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Roman L. Hruska U.S. Meat Animal Research Center
in Cooperation With
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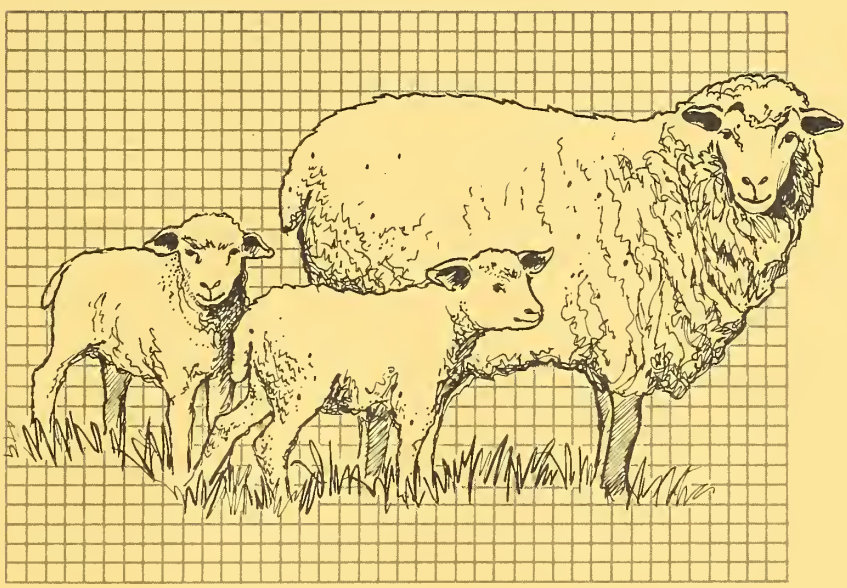
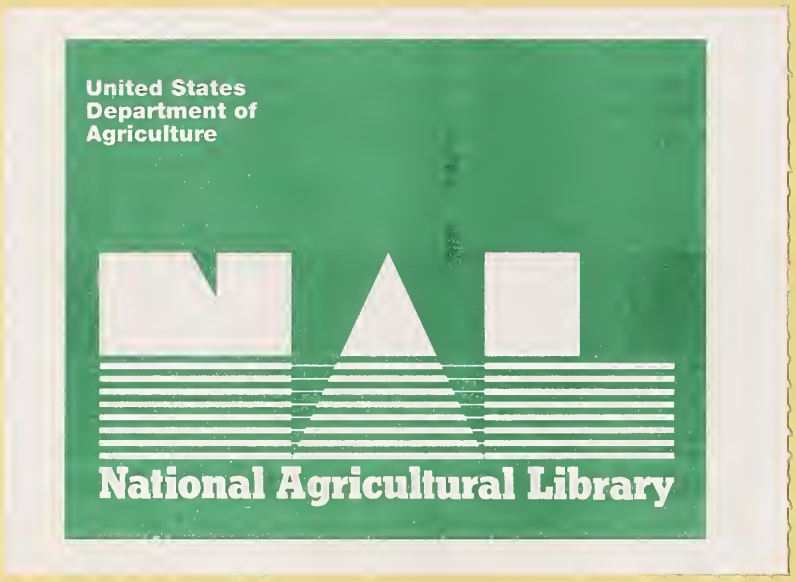
the Agricultural Experiment Station





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CONTENTS

ROMAN L. HRUSKA
U.S. MEAT ANIMAL RESEARCH CENTER[1]

1. Overview of Center: The U.S. Meat Animal Research Center (MARC) was authorized by Congress on June 16, 1964, thereby creating a single facility that provides an unusual opportunity for making major contributions to the solution of problems facing the U.S. livestock industry. Development of the 35,000-acre facility started in the spring of 1966 and is continuing at the present time. Phase I construction, consisting of an office-laboratory building for intensive investigations, was completed in January 1971. These facilities provide a physical plant for 42 scientists and about 200 support personnel. Phase II construction, consisting of the Meats Research Laboratory and the Biological Engineering Building, was completed in October 1977 and provides a physical plant for 25 scientists and about 60 support personnel. Phase III construction will provide for an Animal Health Systems Research Building and a Veterinary Service-Training Facility. Both buildings are scheduled for completion in May 1989 and will accommodate 15 professional and 25 subprofessional employees.

Approximately 50 percent of the research program is devoted to beef cattle, 30 percent to swine, and 20 percent to sheep. Current research program objectives require breeding-age female populations of approximately 7,250 cattle (18 breeds), 4,250 sheep (10 breeds), and 600 swine litters (4 lines) to carry out the various experiments.

The research program at the Center is organized on a multidisciplinary basis and is directed toward providing new technology for the U.S. livestock industry by extending investigations into new areas not now being adequately studied. The research program complements research conducted elsewhere by the U.S. Department of Agriculture and is cooperative with the University of Nebraska Agricultural Research Division and other land grant university agricultural experiment stations throughout the country.

On October 10, 1978, the President signed into law a bill renaming the U.S. Meat Animal Research Center the Roman L. Hruska U.S. Meat Animal Research Center. The purpose of the bill was to honor former Nebraska Senator Roman L. Hruska for "his efforts in the establishment of a centralized facility for the research, development, and study of meat animal production in the United States."

[1]Agricultural Research Service-U.S. Department of Agriculture, the University of Nebraska, and other cooperating land grant universities.

2. Overview of Sheep Research Program: MARC's sheep research program places the highest priority on the development of intensive and semi-intensive sheep production system technology capable of having an immediate impact on the sheep industry. Although the program is largely oriented towards fundamental research, emphasis is placed on the generation of technology that can be practically implemented by small farmers and commercial sheep producers alike within a relatively short time frame. Specific research efforts are not oriented toward wool production problems because research efforts relating to wool are being conducted at state agricultural experiment stations and other USDA research centers.

The sheep research program is organized on a multidisciplinary basis with the focus on solutions to specific problems that represent the greatest technological constraints to improving production efficiency and product desirability. The program is also designed to complement existing domestic and international research programs in the development of sheep production technology.

The contents of this report represent a cross section of our sheep research program at the present time. Since some of the projects from which results are reported are still in progress, the preliminary nature of some of the results must be recognized. However, it is our opinion that information useful to the industry should be provided at the earliest possible time. Progress reports of this nature will be released periodically to make current results available to the sheep industry.

3. Appreciation: I want to express my appreciation to Margie McAlhany, MARC Information Officer, and Mike Wallace, Sheep Operations Manager, for serving as co-editors of this report. I also want to thank Linda Kelly, Secretary to the Director, for proofreading the report. These individuals have contributed many hours to the completion of this report.

Robert R. Oltjen, Director
Roman L. Hruska
U.S. Meat Animal Research Center

Sheep Facilities and Flock Management at MARC

Mike H. Wallace, Gary S. Ross, Robert B. Anderson, and Carrol D. Reutzel[1]

Description of facilities and utilization

The sheep research program at MARC utilizes 1,700 acres of pasture consisting of 160 acres of irrigated brome, 240 acres of warm season perennial, and 1,300 acres of dryland brome. About 4,250 head of ewes are maintained on various levels and types of management to fit research requirements. About 450 purebred and crossbred stud rams are maintained and studied, and over 6,000 head of lambs are produced, fed, and studied yearly.

Eighteen facilities specifically designed for animal handling efficiency, comfort, and welfare are utilized. These include:

- Building 37 — A 1,000-head raised, slotted floor lamb feedlot.
- Building 36 — A 900-ewe raised, slotted floor lambing facility.
- Buildings 31, 32, and 33 — Three 380- to 420-head drylot lambing and feedlot facilities.
- Building 30 — For intensive lamb research projects, automated feed-monitoring devices, surgery, and 250-head artificial rearing facility.
- Buildings 34 and 35 — Two 900-head ewe wintering and lamb feedlot facilities.
- Building 38 — Sale area, covered sorting facility, and shearing facility.
- Pole Sheds 1 and 4 — Two 500-head ewe lambing and lamb feedlot facilities.
- Section 37D — Includes 8 "igloos" modified for ram housing and/or photoperiod control and an enclosed sorting and handling facility.
- Section 84 — Biological Security area includes 4 "igloos" modified for management of imported Texels. Biological security includes control of exit, shower-out, and strict cleaning and disinfecting of all exiting materials.

The levels, breeds, and types of management currently utilized are:

- 420 head of half-Finn ewes shed-lambed yearly in Building 32 for various physiology, meats, and production systems studies.
- 1,000 head of Suffolk and ½-Columbia, ¼ Suffolk, ¼ Hampshire ewes lambed annually at two pole-sheds, primarily utilized for genetics and breeding studies.
- 320 head of half-Finn ewes utilized primarily for reproduction studies at Building 31.
- 320 head of half-Finn ewes lambed annually in Building 33, primarily utilized for nutrition studies.
- 900 head of Finn, Booroola, and various crossbred ewes lambed annually in Building 36, utilized for genetics and breeding studies.
- 1,200 head of Finn; Dorset; ½ Finn, ¼ Dorset, ¼ Rambouillet; ½ Finn, ¼ Suffolk, ¼ Targhee; and Romanov ewes lambed on various 6-month accelerated schedules in Building 36, utilized for genetics and breeding studies.
- 100-300 head of Texel or crossbred ewes lambed annually under strict biological security at Section 84.

[1]Wallace is the sheep operations manager; Ross is the herd health veterinarian; and Anderson and Reutzel are agricultural research technicians, Sheep Operations Unit, MARC.

Flock management

Eleven thousand sheep and lambs at MARC may be on as many as 20 experiments at any one time. MARC has approximately 4,500 ewes lambing throughout the year in lambing facilities varying from slotted floor confinement to conventional drylot shed lambing. Although experimental protocol and facility type dictate variations in management, some standardized procedures are practiced.

Four to six wk before lambing, ewes are sheared, drenched with Levamisol-HC1, vaccinated for types C and D enterotoxemia, and given an injection of vitamins A, D, and E. At this time ewes are switched from a maintenance ration to the late gestation ration (Table 1). During the last trimester (4 to 6 wk) of pregnancy, ewes are closely observed for signs of ketosis (lambing paralysis). Suspect ewes are diagnosed by the use of ketone test strips. Ketones can be detected in the urine before irreversible damage occurs. The testing procedure is relatively simple and inexpensive.

Table 1—Breeding sheep rations

Maintenance Ration—	
42.0% dry matter	97.0% corn silage
10.0% crude protein	0.7% mineral supplement[a]
70.0% TDN	2.3% soybean meal
Late Gestation Ration—	
51.0% dry matter	78.0 % corn silage
13.1% crude protein	0.75% mineral supplement[a]
70.0% TDN	4.25% soybean meal
	7.0 % corn
	10.70% chopped alfalfa hay
Lactation Ration—	
52.0% dry matter	76.0 % corn silage
16.1% crude protein	0.80% mineral supplement[a]
71.0% TDN	8.80% soybean meal
	4.4 % corn
	10.00% chopped alfalfa hay

[a]Mineral supplement consists of: 23% limestone, 34% trace mineralized salt, 34% steamed bone meal, 8% soybean meal, and 720 mg/lb Lasalocid.

When the first lamb in a flock is born, all ewes are switched to a lactation ration (Table 1) with a higher protein density. At parturition lamb navels are bathed in a 7% tincture of iodine solution. A ewe and her lambs are individually penned, or "jugged," and her udder is checked for milk supply and function. Ewes and lambs remain jugged for 1 to 2 days and are observed for nutritional status of the lambs. Lambs not receiving adequate milk are fed 2 to 4 oz of bovine colostrum via stomach tube as needed.

When a ewe can't raise an entire litter, excess lambs are removed for artificial rearing or are crossfostered onto another ewe shortly after tagging (1 to 2 days of age). Tagging involves weighing and eartagging lambs, paint-branding lambs and ewes, and intranasally vaccinating lambs with PI_3-IBR. Ewes and lambs are paint-branded with consecutive numbers starting with the first ewe lambing in a flock. Crossfostering is accomplished by use of the English fostering crate and/or "slime" method.

Lambs to be artificially reared are placed in the nursery facility at 1 to 2 days of age. The 600 lambs entered yearly in the nursery are given 2 to 4 oz of bovine colostrum and trained to the use of nipples. Lambs are self-fed on a commercially prepared ewe milk replacer until weaning at about 4 wk of age. Lambs are docked, vaccinated for contagious ecthyma (sore mouth) and vaccinated with types C and D overeating anti-toxin at 3 to 7 days of age. After weaning, lambs begin an adaptation to the less controlled environment to be encountered when they return to their flock.

At about 2 days post-partum, ewe-lamb(s) pairs are moved to a mixing pen with 5 to 15 other pairs of about the same age. They remain in this group and are closely observed for signs of mis-mothering and health problems until docking with emasculators at about 7 days of age. Two to three days after docking, ewes and lambs in mixing pens are moved to rearing pens containing 15 to 70 pairs. Pairs will remain in their rearing pens until weaning at 42 to 56 days of age, or until they are moved to pasture at 30 days of age (depending on time of year, weather, prescribed weaning age, etc.). Pastured lambs are routinely weaned at 70 days of age. All lambs are given free access to creep feed while in the rearing pens or on pasture.

Weaning procedures vary considerably by flock, age of lambs, and type of rearing facility. In general, the ewe ration is changed to maintenance levels a few days preweaning and ewes are not fed on weaning day. Ewes and lambs are separated. Lambs are weighed; given an injection of vitamin A, D, and E; vaccinated against types C and D enterotoxemia; sorted by sex; and placed back in rearing pens. Lambs weaned off pasture are also drenched with Levamisol-HC1 and placed in drylot. Ewes are drenched with fenbendazole, and individuals are culled. Ewes are culled for: 1) mastitis or any udder dysfunction; 2) vaginal or uterine prolapse; 3) severe emaciation; 4) severe over- or underbite; 5) broken mouth; 6) chronic respiratory problem; 7) rupture; 8) failure to lamb or rear a lamb in two consecutive lambing seasons; 9) failure to keep up with the flock movement during a normal drive. These ewes are sold as slaughter culls. The sound "keeper" ewes are placed on pasture.

After a 2-week postweaning adjustment period, lambs may be moved to or put on various research studies. Lambs are routinely self-fed ground-mixed complete rations.

During the summer, or between weaning and breeding, all ewes are drenched with Levamisol-HC1; their feet are trimmed and bathed for 1 hr in a zinc sulfate-soap solution; and they are shower-dipped for external parasites.

Ewe lambs designated to be saved for replacement stock are sheared; drenched with Levamisol-HC1; vaccinated for BVD, EAE, and vibrio; and moved to pasture at 5 to 6 mo of age and fed limited quantities of concentrates. All replacement ewe lambs are bred at 7 mo of age to lamb at 12 mo. All ewes are drenched with oxfendazol and vaccinated for vibrio and enzootic abortion prior to the 30- to 35-day breeding periods. Most matings are done on a single-sire basis to maintain sire identity.

MARC's 450 stud bucks are sheared during late May and drenched with Levamisol-HC1 during December and July and fenbendazole in September. In March, rams are also drenched with oxfendazol and vaccinated for types C and D enterotoxemia, BVD, and PI_3-IBR. Testicles are palpated for abnormalities at times of drenching. Feet are trimmed and bathed twice yearly. Rams which have abnormalities of feet/legs, mouth structure, testicles, or repeatedly fail to have viable semen tests are sold as slaughter culls.

MARC's sheep research program places the highest priority on the development of intensive and semi-intensive sheep production system technology capable of having an immediate impact on the sheep industry. However, it is the duty and responsibility of the shepherds to ensure that the animals are available and healthy for research projects. Only through disciplined preventive programs such as the one outlined here may MARC's ultimate objective be reached: to help the industry produce red meat more efficiently.

Table 2—Self-fed lamb rations

Lamb Creep, Ground-mixed (Lambs up to 60 lb)—	
17.5% crude protein	20% Alfalfa
80.5% TDN	80% Concentrate[a]
Lamb Ration, Ground-mixed (Lambs 60-80 lb)—	
14.5% crude protein	20% Alfalfa
81.6% TDN	80% Concentrate[a]
Lamb Finishing Ration, Ground-mixed (80 lb to slaughter)—	
11.6% crude protein	20% Alfalfa
82.5% TDN	80% Concentrate[a]
Lamb Grower, Pelleted (Replacement breeding stock 80 lb to first breeding)—	
14.4% crude protein	50% Alfalfa
67.4% TDN	50% Concentrate[a]
Dry Nursery Ration, Ground-mixed (2 days to 28 days for artificially reared lambs)—	
26.2% crude protein	10.0% Alfalfa
87.9% TDN	56.8% Concentrate[a]
	15.0% Dextrose
	5.0% Corn Oil
	5.0% Whey
	0.2% Choline Chloride
	8.0% Oats
Pasture Mineral Supplement—	
	65.0% trace mineralized salt
	16.0% steamed bone meal
	16.0% limestone
	3.0% mineral oil

[a]Concentrate portion includes corn and soybean meal in proportions to meet protein and energy requirements. The following is also included as a portion of the total ration: 1.0% limestone, 0.5% trace mineralized salt, 0.5% steamed bone meal, 0.5% ammonium chloride, plus vitamins A, D, and E, and 22gm/T Lasalocid.

History and Current Status of Booroola Merino Flock at MARC

Larry D. Young and Gordon E. Dickerson[1]

Introduction

On September 17, 1983, 5 Booroola Merino rams and 21 Coopworth ewes carrying Booroola Merino embryos arrived at MARC after a departure from Auckland, New Zealand, on August 11, 1983, and after a quarantine period of about 30 days in Hawaii. The importation was made feasible through a Memorandum of Understanding between the U.S. Department of Agriculture — Agricultural Research Service and the New Zealand Ministry of Agriculture and Fisheries. A history of the Booroola Merino was presented in Progress Report No. 2. Preliminary results of the project that compares the Booroola Merino and Finnsheep is presented elsewhere in this report. The purpose of this article is to describe the attempts to increase the number of purebred Booroola Merinos at MARC.

History at MARC prior to 1986 breeding season

Three of the imported Coopworth ewes did not lamb. The remaining 18 ewes gave birth to 29 lambs (17 males and 12 females). Two ewe lambs and one ram lamb died shortly after birth. The 10 Booroola females were exposed to fertile Booroola rams for a 35-day period starting in mid-December 1984. Prior to lambing, one ewe died from listeria. Only two of the remaining ewes lambed. One ewe had a set of twin ram lambs that lived, and the other had a ewe and a ram lamb that died at birth. This poor conception rate was quite surprising because all Booroola ewes had been detected in estrus at least once in September and October 1984. Consequently, it was decided to breed the Booroola ewes in September and October of 1985. Prior to breeding, one of the nine remaining ewes was killed by coyotes.

Eight Booroola ewes were exposed to fertile Booroola rams beginning about mid-September 1985 until December 30, 1985. Seven of the ewes conceived and produced fifteen lambs (8 males and 7 females) between February 24 and March 21, 1986. Two ewe lambs died at birth from dystocia and one died soon after birth from enteritis. Thus, there were eight mature ewes and four young ewe lambs at the beginning of the 1986 breeding season.

One of the five imported rams died in April 1986 from chronic pneumonia while on loan to the USDA—ARS, U.S. Sheep Experiment Station, Dubois, ID. Four rams born alive at MARC in 1983 have died. The causes and times of deaths were: liver abscess and hepatitis, May 1984; killed by coyotes, June 1985; listeria, September 1985; unexplained anemia while on loan to North Dakota State University, Hettinger, ND, October 1985. A ram lamb born alive in 1985 was extremely small and was destroyed. Thus, for the beginning of the 1986 breeding season, there were 4 imported rams, 13 mature MARC-born rams, and 8 young ram lambs.

[1]Young and Dickerson (retired) are research geneticists, Genetics and Breeding Unit, MARC.

Embryo transfer and natural breeding in fall of 1986

In order to expand the Booroola Merino flock, the eight mature ewes were used as donors in an embryo transfer program in the fall of 1986. Two cycles of embryo recovery were performed on the ewes. The ewes were then bred to carry lambs to term. The first cycle of embryo recovery began in early September. The ewes were synchronized with progesterone pessaries, superovulated with 750 I.U. PMSG, and bred naturally to the imported rams. Fifty-six eggs were recovered from the 8 donors; however, only 15 were fertilized and transferable. The 15 eggs were transferred to 8 recipients (maximum 2 eggs per recipient) and resulted in the birth of 11 lambs (5 males and 6 females). The donor ewes were treated with prostaglandin $F_2\alpha$ and allowed one estrus, which occurred within a few days. The ewes were again synchronized with progesterone pessaries and superovulated with various doses of FSH. During this estrus the ewes were artificially inseminated with fresh semen directly into the uterus via laparoscopy techniques. Semen was collected from the four imported rams. From this cycle, 73 eggs were recovered, and 70 were fertilized and transferable. The 70 eggs were transferred to 37 recipients and resulted in 45 lambs (17 males and 28 females). From the two cycles of embryo transfer, 19 males and 33 females were alive at 1 mo of age.

After the second embryo recovery, the 8 donor ewes were again treated with prostaglandin $F_2\alpha$ and bred at the first subsequent cycle. The 8 mature ewes and the 4 ewe lambs born in 1986 were penned with individual Booroola rams from October 13, 1986, until December 5, 1986. Seven of the eight mature ewes lambed and produced 16 lambs (6 males and 10 females). Two of the four ewe lambs lambed and produced 3 lambs (2 males and 1 female). At 1 mo of age, 5 males and 8 females were still alive from mature ewes and ewe lambs.

Summary

As of May 1, 1987, the inventory of Booroola rams consisted of 4 imported rams, 21 mature rams born at MARC, and 24 ram lambs less than 4 mo old. The inventory of Booroola ewes consisted of 12 mature ewes born at MARC and 41 ewe lambs less than 4 mo old.

7-month-old of Booroola Merino ewe lamb.

Performance of Progeny of Booroola Merino and Finnsheep Rams

Larry D. Young and Gordon E. Dickerson[1]

Introduction

A major component of sheep breeding research at MARC has focused on the use of Finnsheep in crossbreeding programs to increase reproductive rate. Ovulation rate and litter size in Finnsheep are controlled by a large number of genes, each having a small effect. Research has shown that for every 1% increase in Finnsheep breeding in the ewes, there is a 1% increase in lambs born per ewe. Consequently, Finnsheep have been used widely to produce crossbred ewes for intensive lamb production in commercial flocks, particularly in crop farming areas. Despite the documented advantage in prolificacy of crossbred Finnsheep ewes, they have not been used in some segments of the sheep industry because of their smaller size, slightly poorer quality and quantity of wool, and a presumed lack of hardiness under range conditions.

The Booroola Merino is an alternative source of genes for increasing prolificacy. Its litter size is among the largest in the world. The Booroola Merino is most unique because its increased ovulation rate (and consequently increased litter size) is controlled by genes at a single major locus. The Booroola Merino is the only highly prolific breed with an unpigmented, Merino-quality fleece. This should make the Booroola Merino more acceptable than the Finnsheep as a genetic source of increased prolificacy for segments of the U.S. sheep industry that emphasize wool production.

With the cooperation of the New Zealand Ministry of Agriculture and Fisheries, 5 adult Booroola Merino rams and 21 Coopworth ewes impregnated with Booroolo Merino embryos were imported to MARC in the fall of 1983. A project involving the Finnsheep and Booroola Merino was initiated in December of 1983. This project has many objectives, but the purpose of this report is to present preliminary results of the comparison of Finnsheep and Booroola Merino in top-crosses on a third breed for lamb survival, lamb growth, lamb carcass quality, ewe reproduction, and wool production.

Procedure

Seventeen Booroola Merino and thirteen Finnsheep rams were mated to an equal number of crossbred ewes (½ Columbia, ¼ Suffolk, and ¼ Hampshire) for 35 days beginning in mid-December of 1983 and 1984. Matings were in outside dirt lots with approximately 20 ewes and one ram per pen. Lambs were born and raised on elevated woven-wire floors. Lambs were weighed at birth and at an average of 9 (weaning), 12.5, and 20 wk of age. Rams not needed as replacements were slaughtered in groups of approximately 60 after reaching 100 lb liveweight, and carcass data were recorded. All healthy ewe lambs were monitored for age at first estrus by exposure to vasectomized rams beginning at 20 wk of age. At approximately 7 mo of age, all sound and healthy ewe lambs were exposed to fertile rams for 35 days. Breeding marks were recorded three times a week prior to breeding and daily during breeding. Ovulation rate was evaluated by laparoscopic examination 7 to 10 days after the first mating of each ewe to a fertile ram. Ewes were weighed at the beginning of each breeding season. Fleece weight was recorded at shearing one mo prior to lambing at 2 yr of age for ewes born in 1984.

Results

Results of analyses of data collected on lambs born in 1984 and 1985 are presented in Table 1. Lambs sired by Booroola and Finnsheep rams had virtually the same birth weight, but Finnsheep-sired lambs were significantly heavier than Booroola-sired lambs at 9 and 20 wk of age. Daily gain measured from 9 to 20 weeks of age was equal for the two breeds. Thus, the difference in 20-wk weight was due entirely to differences in preweaning growth. Finnsheep crosses had a slightly higher survival rate to weaning than did Booroola crosses.

Percentage of ewe lambs cycling by the end of their first breeding season was significantly higher for Finnsheep crosses than for Booroola crosses. Finnsheep crosses were also about 11 days younger at first estrus than Booroola crosses. The number of corpora lutea represents the number of eggs shed and thus the upper limit to number of lambs born. For ewes mated to fertile rams, Booroola Merino crosses had a higher ovulation rate. However for ewe lambs that lambed, Finnsheep crosses had a larger litter size and a higher egg survival rate than Booroola crosses.

Carcass weight at 195 days of age was higher for Finnsheep crosses than Booroola crosses, which reflects the differences in preweaning growth. There were no differences in quality score. Booroola crosses had more external fat, but Finnsheep had more internal kidney fat. Dressing percentage was lower for Booroola crosses, which probably reflects the differences in pelt weight and kidney fat. Pelt weight was likely heavier for Booroola crosses because they produce more wool and the rams were not shorn. The kidney fat is included in carcass weight which would increase carcass weight of Finnsheep crosses.

At 7 mo of age the Finnsheep cross ewes were 12 lb heavier than the Booroola-cross ewes. This difference was approximately 10 lb for 19-mo-old ewes. This indicates that the breed differences in preweaning growth are still present at considerably older ages. Fleece weight was available only on 1984 born ewes prior to lambing at 2 yr of age. As expected, the Booroola crosses had considerably heavier fleeces than the Finnsheep crosses.

These results indicate that, relative to Finnsheep, Booroola crosses will have a higher ovulation rate as ewe lambs but will not necessarily produce more lambs. Booroola crosses will also produce more wool. However, Booroola crosses will not reach puberty or market age as soon as Finnsheep crosses. At a constant carcass weight, both crosses will produce carcasses of desirable quality, but Booroola crosses will have less internal fat and more external fat. These results should be considered preliminary because similar data will be available on lambs born in 1986 and 1987. However, the results were consistent for the 2 yr reported here.

[1]Young and Dickerson (retired) are research geneticists, Genetics and Breeding Unit, MARC.

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The genetic mechanisms controlling prolificacy in the Booroola Merino and the Finnsheep offer different approaches to increase reproductive rate in crossbred and purebred populations: 1) both breeds could be used to produce first-cross ewes; 2) the Finnsheep could be used to optimize the genetic level for reproduction in a composite population; or 3) the Booroola Merino fertility gene could be introduced into any other breed by backcrossing and selection. Crossbred ewes developed from the Booroola Merino can have only two levels of increased prolificacy (one or two copies of the Booroola gene). If the resulting prolificacy is more than optimum for the production situation, the use of Finnsheep germ plasm may be more appropriate. Since a large number of genes appear to be responsible for the increased prolificacy of the Finnsheep, the appropriate level of Finnsheep germ plasm can be introduced into the crossbred or composite population to achieve optimal prolificacy, provided the effects of undesired genes from Finnsheep are negligible. After several generations of backcrossing and intense selection for ovulation rate, it should be possible to introduce the Booroola gene into any sheep population, increase its frequency to a very high level, and reduce the frequency of other Merino genes to very low levels. This approach would be most appropriate if the high level of prolificacy provided for by the homozygous (two copies of the gene) Booroola genotype is optimum. Matings within flocks that are not homozygous for the Booroola gene will result in three subpopulations (those carrying zero, one, or two copies of the gene), which may complicate management.

Table 1—Mean performance of Booroola Merino (B) crosses and Finnsheep (F) crosses born in 1984 and 1985

Trait	No. of Observations		Means	
	B-crosses	F-crosses	B-crosses	F-crosses
Birth weight, lb	186	181	11.64	11.60
9-wk weight, lb	160	168	49.82*	56.44
20-wk weight, lb	153	156	91.49*	97.66
Daily gain, lb/day	153	156	.52	.52
Lamb survival, %[a]	186	181	88.5	92.3
Percent cycling	78	85	56.9*	90.2
Age at 1st estrus, days	41	71	188.7*	177.1
No. of corpora lutea	28	64	1.86	1.65
Litter size	20	54	1.30	1.53
Egg survival rate, %	20	54	67.0*	94.4
195-day carcass weight, lb	76	74	60.63*	64.60
Carcass quality score[b c]	76	74	12.3	12.3
12th rib fat, in[c]	76	74	.20*	.17
Est. % kidney fat[c]	76	74	2.81	2.94
Dressing percent[d]	76	74	53.1*	55.6
7-mo ewe weight, lb	44	56	93.7*	106.9
19-mo ewe weight, lb	28	11	132.5*	142.9
2nd-yr fleece weight, lb	28	11	9.66*	6.50

[a]Number weaned/number born dead or alive, excluding nursery-reared lambs (8 per sire breed).
[b]Score of 12 = high choice and 13 = low prime.
[c]Adjusted to a constant carcass weight of 62 lb.
[d]Adjusted to a constant slaughter weight of 115 lb.
*$P<.05$ for difference between breed group means.

Importation of the Texel Breed

Kreg A. Leymaster, Gordon E. Dickerson, and Thomas G. Jenkins[1]

Introduction

The primary objectives of sheep production are to reduce the cost of production and to improve product quality, the relative amounts of lean and fat in meat from lambs. These objectives are compatible with each other and relevant to problems facing the sheep industry today. Sheep producers face long-term industry challenges from consumers with real or perceived concerns about the dietary-health issues presently associated with red meats. Consumers seek nutritious, wholesome meat that is low in saturated fat and cholesterol content. Excessive fat is economically inefficient to produce and detrimental to product acceptability. Consequently, the reduction of fat is an important goal of the sheep industry.

Useful genetic variation exists among sheep breeds for carcass leanness and fatness. These breed differences can be exploited rapidly and cheaply relative to selection within a breed. Therefore, experimental evaluation of the most promising breeds throughout the world is an effective approach to improve carcass leanness. Identification of superior breeds provides a basis for substituting more desirable breeds for less desirable breeds. The benefits of additive (breed transmitted effects) and nonadditive (heterosis) genetic effects can then be realized through production of established pure breeds, use of crossbreeding systems, or formation of new composite populations.

The Texel breed is widely recognized for its superior carcass leanness relative to European breeds of sheep. The first importation of Texels into North America occurred at MARC during 1985. The history of the breed, production levels for important traits, importation procedures, and experimental plans are described.

History

The Texel breed is native to The Netherlands (Holland), having evolved on the Isle of Texel. Its ancestors belonged to a group of white-faced, short-tailed marsh sheep that populated the coast from Denmark to Northern France. The dominant British lamb market required a meaty carcass in the early 19th century. To compete in this market, the sheep producers on the Isle of Texel obtained a breed inspector in 1802. The main responsibility of the inspector was to organize shows for the purpose of maintaining breed purity and of influencing meat characteristics. To improve meatiness, the Texel breed was crossed with Leicesters in 1846 and with Lincolns in 1880. Upgrading to these breeds was not successful, and no additional crossbreeding occurred. Further genetic improvement was a consequence of selection among sheep on the Isle of Texel. The judging of rams at central shows was a dominant force in this selection process.

The success of the selection program resulted in widespread exportation of Texels to other countries beginning in the 1930's. France, Belgium, and Luxemburg were among the first countries to import Texels. Other countries that have imported Texels directly from The Netherlands include the Federal Republic of Germany, Italy, Brazil, Peru, Spain, Denmark, Switzerland, and the United Kingdom. Further dispersion of the breed has occurred through these countries.

Performance

The Texel breed has been evaluated as a terminal sire breed in numerous European studies. Eight such studies have compared the performance of progeny by 21 sire breeds. Each experiment included the Texel breed, with the Suffolk, Oxford, and Ile de France breeds being used most frequently. Results of these experiments were in agreement with regard to growth and carcass composition. Texel-sired lambs grew less rapidly than Oxford- and Suffolk-sired lambs, but more rapidly than lambs sired by Ile de France rams. Texel-sired lambs excelled in percentage carcass lean (+4%), percentage carcass fat (-4%), lean-to-bone ratio, and loin eye area. These results provided the basis for importation of the Texel as a breed that might improve carcass leanness in the U.S.

The reproductive performance of Texel ewes has not been compared to any breeds presently available in the U.S. Such information is important because it relates to the industry cost of maintaining the pure breed. Additionally, reproductive data permits extension of breed usage from terminal sire application to potential use as a generalized or maternal breed. The performance of purebred Texel ewes for various reproductive traits has been reported by Dutch scientists. Ewe lambs exhibited a breeding season that averaged 63 days, compared to 114 days for ewes that were 18 mo of age. A 5-mo breeding season is common for mature ewes. Lambs born per ewe lambing averaged 1.31 for ewe lambs and 1.84 for older ewes, based on analysis of 60 yr of records. Concern has been expressed about ewe longevity and lamb mortality associated with lambing difficulty. These important traits will be monitored during research conducted with Texels at MARC.

Importation

During 1984 an opportunity developed to import the Texel breed into MARC. At that time, the Ministry of Agriculture and Fisheries of New Zealand was importing several European breeds, including the Texel, into New Zealand from Finland and Denmark. Arrangements were made to import into the U.S. a sample of Texel ewes and rams that had previously produced embryos which were frozen for importation into New Zealand. This effort involved the cooperation of numerous administrators, veterinarians, and scientists in the U.S., New Zealand, Finland, Denmark.

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Because of the health status of livestock in Finland and Denmark, a quarantine site was constructed at MARC during late 1984. Following a 30-day temporary quarantine in New York, five Texel rams from Denmark arrived at MARC on January 4, 1985. This was followed by the arrival of 20 pregnant ewes and 4 rams from Finland on April 25, 1985. These ewes were bred by the four rams imported from Finland plus one ram that was not imported. The imported ewes were of the following ages: 3-yr-old, 3; 4-yr-old, 2; 5-yr-old, 2; 6-yr-old, 1; 7-yr-old, 2; 8-yr-old, 7; 9-yr-old, 1; and 10-yr-old, 2. The 20 ewes produced 35 lambs during the spring of 1985, a drop rate of 1.75.

During the fall of 1985, the Texel ewe flock was synchronized and single-sire mated to four rams from Denmark. Nineteen of the 20 imported mature ewes lambed in 1986 and produced 32 lambs, a drop rate of 1.68. Fourteen of the 15 1985-born ewes also lambed and produced 15 lambs, with average age-at-parturition of 349 days.

The flock is now managed on a 12-mo production cycle. Culling is practiced to maintain structural and reproductive soundness. A total of 55 ewes were exposed to rams during November 1986, including all 20 imported mature ewes. The flock will continue to expand during the quarantine period that is scheduled to be terminated in the spring of 1990.

Experimental plans

The Texel breed will be evaluated for genetic effects on growth, carcass leanness, and feed intake under two diets differing in energetic density. Texels will be compared to Suffolks. Rams of these two breeds will be mated to commercial ewes, and the resulting crossbred progeny used to evaluate effects of sire breed. This experiment is necessary, despite the previous evaluations of Texels in European studies, because North American Suffolks apparently have greater growth potential than Suffolks available in other countries. The experiment will be conducted during 1988 and 1989 so that results will be available to the sheep industry when the Texel breed is released from quarantine.

13-month-old Texel ewe lamb.

Importation of Romanov Sheep

Larry D. Young and Gordon E. Dickerson[1]

Introduction

Rate of reproduction is one of the most important factors in determining the efficiency of any animal production system. Rate of reproduction can be increased through improved environment or improved genetics. Genetic improvement of the commercial flock may result from selection or crossbreeding. Selection within a breed for increased reproduction would be possible but very slow. However, reproduction of the commercial ewe flock could be increased rapidly by crossbreeding to a prolific breed. There is considerable variation among sheep breeds in reproductive performance and several breeds with exceptionally high reproductive performance have been identified in other countries. In the early 1960's, the prolific Finnsheep was imported into the U.S. through Canada. This breed has been used extensively to improve reproduction of commercial crossbred ewes. In 1983, MARC imported the Booroola Merino, which has not yet had a significant impact on the commercial industry primarily because of low numbers of imported animals. These two breeds do increase rate of reproduction but have other weaknesses and are not completely acceptable in all production situations. Therefore, it is important to import and evaluate additional prolific breeds that may be useful to other segments of the commercial sheep industry.

History

The Romanov originated in the Soviet Union in the 18th century. The current belief is that the Romanov was developed from a short-tailed Nordic breed by selection over many years. The Romanov takes its name from a small town in the Volga Valley, northeast of Moscow, not very far from where the Finnish Landrace originated. In fact, many scientists believe that the two breeds have the same origin and trace back to the European mouflon. In the conditions of that time, a farmer obtained up to 175 lb of fresh mutton, two or three sheepskins, and up to 8 lb of wool from the offspring of one ewe. In fact, during that time the sheepskins were almost as important, if not more so, than the meat. Consequently, number of lambs was more important than size or growth rate.

Breed characteristics

The Romanov is of interest to U.S. producers because of its early puberty, excellent prolificacy and excellent mothering ability. The lambs are all black at birth, except most have a white spot on the forehead, and then they turn gray as a result of a mixture of black and white wool fibers. The males have a mane of long black hair around the neck and the brisket. The sheepskin of the Romanov is distinguished by a high ratio of guard hair to down (from 1:4 to 1:15). The great length of the down fibers above the guard hair, their resistance to interweaving, their good thermal insulation properties, and the fineness of the wool make the Romanov sheepskin especially valuable.

The head is small and angular; the poll is round; and the ears are upright and mobile. The tail is short and pointed. The body is of medium size, and the ribs are rounded. The average body weight of the mature animal is 110 lb for ewes and 155 lb for rams.

Sexual maturity is early in the Romanov. Males are capable of mating at 3 to 4 mo of age, and some ewe lambs have lambed at 9 mo of age. The Romanov apparently has a long season of sexual activity. Ewes often return to estrus 30 to 40 days after lambing and have an average gestation length of 144 days. Most ewes are able to nurse three lambs. In Canada the average litter size was 2.86 lambs. The high litter size of the Romanov results from a high percentage of ewes giving birth to twins and triplets rather than a small percentage having exceptionally large litters.

Importation

In October 1980, 14 ewes and 5 Romanov rams were imported from France by Agriculture Canada. The sheep were placed under a five-year quarantine at the Lennoxville Research Station in Quebec, Canada. Over the five-year quarantine, the numbers were increased rapidly by using an accelerated lambing system of lambing three times in two years. In October of 1986, Agriculture Canada, Lennoxville, sent 16 pregnant Romanov ewes and 4 Romanov rams to MARC in exchange for 15 open Finnsheep ewes and 5 Finnsheep rams. Thirteen of the ewes have lambed and produced 45 lambs, including three sets of twins, six sets of triplets, four sets of quadruplets and one set of quintuplets.

Experimental Plans

During the next couple of years, the Romanov flock will be expanded to provide sufficient numbers for future research. The exact program has not been identified completely but will likely include the comparison of Romanov, Finnsheep, and some other breeds in a diallel crossing experiment that will evaluate life cycle performance. The other breeds being considered are the Rambouillet, Texel, and Suffolk.

10-month-old Romanov ewe lambs.

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Body Composition and Maintenance Feed Requirements in Seven Breeds of Ewes

John C. Olthoff and Gordon E. Dickerson[1]

Introduction

Roughly two-thirds of total feed used in sheep production is required to simply maintain vital body functions; only the remaining one-third is used for pregnancy, lactation, and deposition of body protein and fat. Other research has indicated that genetic reductions in fatness or increases in milk production or prolificacy may increase the proportion of more metabolically active lean tissues in the body, and thus increase the maintenance feed required. In order to predict the net effect of such genetic changes on feed cost per unit of lamb and wool output, further evidence of their effects on body composition and maintenance feed requirements was needed.

This report summarizes results from an experiment relating detailed body composition to calorimetric measures of basal metabolism and to feed intake in mature open, dry ewes of seven genetically diverse breed types[2]

Procedure

Twelve mature open, dry, 3-to 4-yr-old ewes from each of seven breeds were included in a study of the association of body composition with basal metabolism and feed consumption. Breeds used were Rambouillet (R), Dorset (D), Finnsheep (F), Suffolk (S), and three new composites obtained by mating several generations within a 3-breed cross population: I (½ F, ¼ R, ¼ D), II (½ F, ¼ S, ¼ Targhee), and III (½ Columbia, ¼ S, ¼ Hampshire).

A pelleted alfalfa diet was fed *ad libitum* to all 84 ewes for 3 wk, using body weight changes and feed intake to predict later intake required to maintain body weight. Ewes of each breed were shorn and divided into *ad libitum* (AL) and maintenance (MN) fed sets of three like-sized pairs of ewes over a 5- to 8-wk period, with feed intake and weight changes recorded weekly.

Then ewes were fasted for 56 hr, shorn again, and the basal metabolic rate (i.e., heat production) measured over 16 hr (3 p.m. to 7 a.m.) by indirect calorimetry. Activity was videotaped and heat output calculated at 10 min intervals to permit later adjustment to uniform (zero) activity basis.

Immediately after calorimetry, each ewe was slaughtered and divided into four fractions based upon expected differences in metabolic activity: visceral organs and blood (ORB); gastrointestinal tract plus internal fat (GIF); head, hooves, and pelt (HHP); and carcass (CAR). Weights of individual components of these fractions also were taken. Carcasses were split between ribs 12 and 13 for measurements of backfat and bodywall thickness, and area of *l. dorsi* muscle cross-section of both sides. Each fraction except pelt was frozen and ground three times through a 6.35 mm plate. Duplicate 200-g samples were collected from numerous subsamples of each ground and mixed fraction and chemically analyzed for water, fat, ash, and fat-free dry organic (protein) content.

Results

Resting maintenance. During the initial 3 wk adjustment period of *ad libitum* feeding, the ewes later assigned to maintenance-level feeding (MN) gained similarly (11 lb) but averaged over 8 lb lighter than those continued on AL feeding (Fig. 1). During the following 5-wk experimental period, feed intake increased slightly for AL ewes but was reduced over one-third for the MN ewes. The AL ewes gained another 6 lb, whereas the MN ewes lost 8 lb in the first week but maintained weight thereafter. However, after fasting for 56 hr, shrink was greater for AL fed ewes and their average weight in the calorimeter was only 15 lb (10%) above MN ewes (Table 1). Fasting heat production (FHP) per ewe was 8% higher for AL than for MN ewes, but when expressed per unit of metabolic size ($wt^{.75}$), there was no consistent difference between feeding levels.

The range in breed differences was large in ewe weight (58% of mean) and in daily fasting heat production (40% of mean). However, when expressed per unit of metabolic size, breed differences in FHP were small relative to errors of measurement (7% of mean).

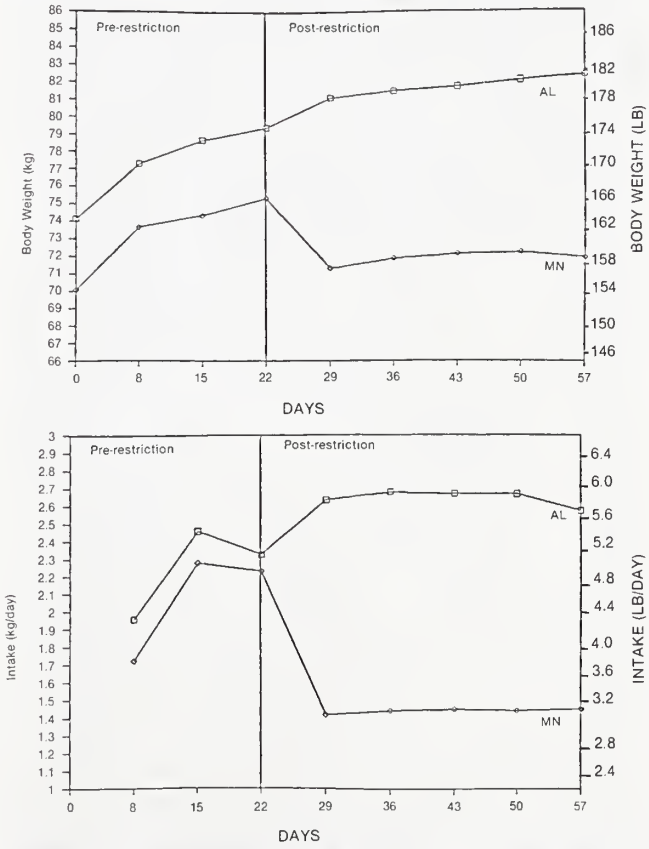

Figure 1—Average weight and daily feed intake of ewes assigned to *ad libitum* (AL) or maintenance (MN) feeding levels.

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[2]John C. Olthoff. 1985. Relationship among feed intake body composition and fasting heat production in mature ewes. Ph.D. Thesis, Univ. Nebraska Library, 176 pp.

Table 1—Ewe weights in calorimeter and fasting heat production (FHP)[a] by breed and feeding level[b]

Breed	Ewe weight (lb)			FHP (Kcal/day)			MFHP (Kcal/kg$^{.75}$)		
	Ad lib	Maint.	Avg	*Ad lib*	Maint.	Avg	*Ad lib*	Maint.	Avg
			***			***			
Finn	130	103	117	1480	1370	1425	70.6	76.3	73.5
Dorset	144	127	136	1725	1610	1667	72.5	77.2	74.8
Rambouillet	166	132	149	1785	1600	1692	69.7	74.5	72.1
Compos II	164	129	147	1710	1635	1672	67.7	79.2	73.4
Compos I	143	136	140	1555	1555	1555	68.3	70.6	69.4
Suffolk	183	190	186	2335	1915	2125	79.9	67.7	73.8
Compos III	204	211	207	2200	2105	2152	69.8	70.4	70.1
Mean	162*	147	155	1825**	1685	1755	71.2	73.7	72.9

[a]Adjusted for activity to a lying position basis.
[b]Probability of differences this large due to chance less than 5% for *, 1% for **, and 0.1% for ***.

Body composition. Breed differences in fat content of the empty body were large and real, ranging from 30% for Finn to 39% for Composite III ewes, and were very similar for their carcasses (Table 2). Fat content of head, hooves, and pelt (HHP) was about one-half that of carcasses, while fat in organs and blood (ORB) ranged only from 3 to 4%. Internal fat included in the GI tract (GIF) averaged nearly twice that in carcasses (CAR), but the breed range (58 to 66%) was small relative to sampling errors. Total empty body fat content averaged 2% higher in ewes fed *ad libitum* than in MN ewes, but 3.7% higher for GI tract with internal fat and only 1.4% higher for carcass and 0.6% higher for organs and blood.

Because metabolic activity of protein in visceral organs and blood is expected to be higher than in muscle, breed differences in the distribution of body lean tissue (water + protein) among body fractions are of interest (Table 3). Breed differences in percent of total body lean located in each fraction were large and real, ranging from 55 to 60% for carcass, 18 to 21% for HHP and 10.3 to 12.7% for both GI tract + fat and organs + blood. Finn ewes were highest in body lean (70%), had most lean in GI tract and organs + blood (25.4%), and were among higher breeds in FHP per unit of metabolic size (MFHP, Table 1). Composite III ewes had least body lean (61%), lowest proportion in GI tract and ORB (20.8%), and were among lowest in MFHP. However, the association of breed mean composition with measured heat production/unit of metabolic size was not close. Feeding level had no effect on distribution of lean tissue among body fractions.

Body composition and resting maintenance. Correlations of resting heat production (FHP/day) with weights of body-fractions and their chemical components among ewes of all breeds and feeding levels (Table 4) tell something about which body components contribute most to maintenance requirements. Correlations were highest for total weight of body or carcass, and for weights of water or of lean tissue in total body, carcass, or GI tract. Correlations were lower with fat and ash. Correlations with protein probably were lower than for water because protein was calculated as organic matter remaining after subtracting measured water, fat, and ash. These correlations of FHP with weights of different body fractions were relatively similar because all of them were closely associated with variation in total body weight.

A better indication of relative metabolic activity for different body fractions and chemical components is their correlation with heat production per unit of metabolic size (MFHP, kcal/wt$^{.75}$, Table 5). The correlation of FHP/day with empty body weight $^{.75}$ was .84, nearly the same as

Table 2—Fat content (%) in fractions of empty body by breeds and feeding level[a]

Breed	TOTAL	CAR	ORB	HHP	GIF
	**	***	*	***	NS
Finn	30.2	28.8	3.1	12.0	57.8
Dorset	32.2	32.3	2.9	15.2	58.3
Rambouillet	32.1	31.4	3.6	15.6	61.6
Compos II	34.4	33.6	3.0	15.3	60.8
Compos I	35.4	33.4	3.2	14.3	66.1
Suffolk	35.7	36.1	2.8	17.1	62.2
Compos III	39.0	39.6	3.8	20.3	65.5
Feed Level	≠	NS	**	NS	*
Ad libitum	35.2	34.3	3.5	15.5	63.6
Maintenance	33.0	32.9	2.9	15.8	59.9

*Probability of differences this large from chance alone are over 10% for NS, less than 10% for ≠, 5% for *, 1% for **, and 0.1% for ***.

Table 3—Distribution (%) of lean tissue among body fractions by breed and feeding level[a]

Breed	CAR	GIF	HHP	ORB
	***	***	*	**
Finn	54.8	12.7	19.8	12.7
Dorset	57.7	11.3	19.8	11.2
Rambouillet	57.6	10.4	20.3	11.6
Compos II	56.2	12.1	19.5	12.2
Compos I	57.5	11.4	19.3	11.7
Suffolk	60.2	10.6	18.2	11.0
Compos III	58.6	10.5	20.7	10.3
Feed Level	NS	NS	NS	NS
Ad Libitum	57.4	11.6	19.4	11.5
Maintenance	57.6	11.0	19.9	11.6

[a]Probability of differences this large from chance alone are over 10% for NS, less than 5% for *, 1% for **, and 0.1% for ***.

Table 4—Correlations of fasting heat production (Kcal/day) with weights of empty body fractions and chemical components[a]

Chemical Components	Empty body fractions				
	Total	Carcass	GI + internal fat	Head, hooves, and pelt	Organs and blood
All	.85	.86	.68	.75	.80
Fat	.77	.81	.59	.70	.63
Ash	.75	.73	.61	.56	.79
Protein	.80	.80	.33	.73	.79
Water	.86	.84	.84	.74	.78
Lean	.86	.85	.83	.75	.79

[a]Less than 1% probability that any of these correlations could be due only to chance in sampling.

Table 5—Correlations among metabolic fasting heat production (MFHP) and percentages of empty body weight for fractions and chemical components[a]

Chemical composition (%)	Empty body fractions (%) Carcass	GI tract + fat	Stomach + large, small intestines	Head, hooves, pelt	Organs and blood	MFHP Kcal/ $wt^{.75}$/day
Fat	.33	.52	-.54	-.59	-.82	-.52
Ash	-.09*	-.32	.24	.30	.38	.44
Protein	-.25	-.26	.32	.36	.51	.34
Water	-.31	-.53	.56	.59	.83	.52
Lean	-.33	-.50	.54	.58	.81	.50
MFHP	-.11*	-.36	.42	.27*	.52	---

[a]Based on 42 ewe pairs for correlations with MFHP but on 84 ewes for others.
*Greater than 10% probability that these correlations could have occurred by chance alone, others less than 5%.

Table 6—Best linear partial regression prediction of fasting heat production (Kcal/day) from weights of body components[a]

Chemical component	Intercept	b_1 Carcass	b_2 GI tract + fat	b_3 Organ + blood	R^2
Empty body weight (lbs)	940	8.2		65.8	.78
Water	795	15.9	99.3		.77
FFDOM[b]	1005	47.2		338.8	.69
Lean[c]	774	13.2	78.9		.77

[a]FHP/day = Intercept + $b_i X_i$, where b_i is partial regression/lb of weight of body fraction indicated.
[b]Fat free dry organic matter = protein.
[c]Lean = water + FFDOM.

with weight itself. The effect of percent body composition on MFHP is shown by its correlation of -.52 with percent fat, .52 with percent water, .50 with percent lean, .52 with percent organs and blood, and .42 with percent stomach and intestines without internal fat.

Another kind of evidence for the greater influence on FHP of lean tissue in GI tract or visceral organs plus blood than of lean in the carcass is the relative size of the partial regressions of FHP on each (Table 6). Notice that a change of 1 lb in organs + blood had 8 times larger effect on FHP than a change of 1 lb in carcass weight (65.8 *vs* 8.2). If prediction of FHP is based upon weight of water in carcass and GI tract, GI water is 6 times more active (99 *vs* 16). Similarly, partial regressions for protein (FFDOM) are 7 times larger for organs + blood than for carcass, and those for lean tissue are 6 times larger for GI tract than for carcass.

If FHP/day is expressed per lb of body lean tissue, this accounts for about 74% of the total variation in FHP among ewes of the seven breeds. In Figure 2, FHP/lb of lean body tissue is plotted against percentage of total body lean located in the GI tract, visceral organs, and blood. Proportion of total lean located in viscera and blood accounted for 90% of the variation among breed means in FHP/lean weight, again emphasizing the greater metabolic activity of viscera and blood compared with carcass lean tissue. The Finn ewes were not only leaner than Composite III ewes (70 *vs* 61%, Table 2), but also had 25.4 *vs* 20.8% of their total lean in viscera + blood (Table 3), which accounted for 14% higher FHP/unit of total lean for Finn than for Composite III ewes. The other five breed means were intermediate and conformed amazingly well to expected values.

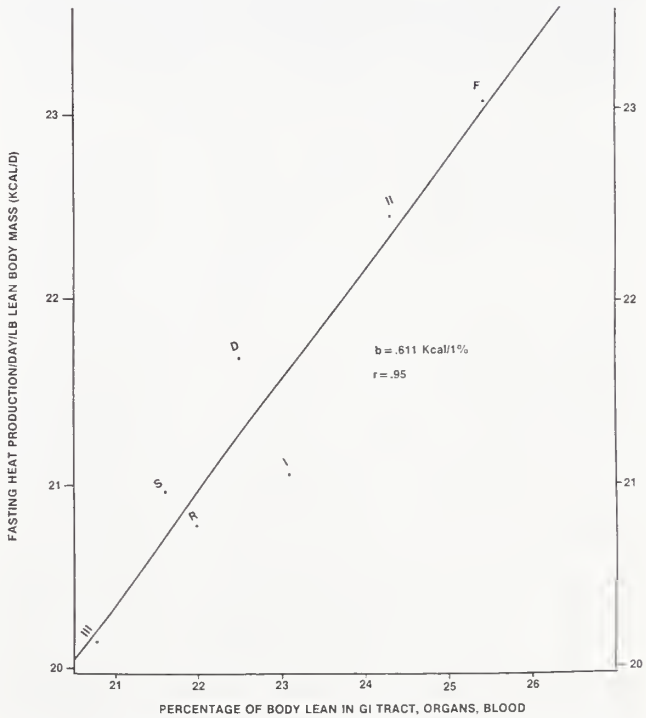

Figure 2—Breed mean association of daily fasting heat production/lb body lean with proportion of total lean located in visceral organs and blood.

Restricted feeding and maintenance requirements. After the initial drop in gut fill (Fig. 1) when MN ewes were placed on less than 60% of *ad libitum* level of feed intake (Table 7), there was little further change in weight. There was some loss in condition of MN ewes, especially of internal fat (GIF, Table 2), compared with AL ewes. However, the restricted feed intake caused only a slight reduction in the proportion of body lean in the viscera (Table 3). The slight increase in fasting heat production per unit of metabolic size (Table 1) can be explained by the reduced fill and higher lean content of MN ewes (Table 2) and by the 6% higher average daily FHP/lb of lean mass (22.1 *vs* 20.8 Kcal) for MN ewes.

The level of feed intake required to maintain body weight and condition with normal actual levels of eating, ruminating, and other activity naturally is higher than measured overnight at zero activity in the calorimeter chamber (160 Kcal/kg$^{.75}$, Table 7, *vs* 73 Kcal/kg$^{.75}$, Table 1).

Conclusions

Breeds differ greatly in body size, and this accounts for the major differences in feed intake required to maintain normal life functions. However, breeds also differ in body fat content and in the proportion of their lean tissues located in the metabolically more active visceral organs and blood relative to carcass muscle. Maintenance requirements are important in choosing breeds for use to produce replacement breeding females or only to sire market lambs, because the ewe flock accounts for roughly two-thirds of total feed consumed. Feed maintenance requirements of breeds can be predicted most accurately when information is available on body composition and distribution of lean tissue between visceral organs and blood *vs* less active carcass muscle. Such information is useful in predicting the relative net efficiencies of ewe breeds which differ in performance characteristics.

Table 7—Actual daily metabolizable energy intake per unit of metabolic size (Kcal/kg$^{.75}$) by breed and feeding level, and estimated maintenance requirement, by breeds

Breed	Actual feed intake			Maintenance requirement[a]
	AL	MN	Mean	
			***	*
Finn	185	116	150.6	190
Dorset	197	106	151.5	192
Rambouillet	176	105	140.5	174
Compos II	183	104	143.6	166
Compos I	177	112	144.3	175
Suffolk	188	121	149.3	178
Compos III	207	109	157.8	192
Mean	188***	110	148.8	180[b]

[a]Predicted intake/day to maintain constant body *weight*.
[b]Estimated mean intake requirement to maintain constant body *energy* content was lowered to 160 Kcal/kg$^{.75}$, when lower digestibility for *ad libitum* intake was considered.
Probability of differences this large are less than 5% (*) or 0.1% (***).

Feeding Behavior of Ram Lambs as Characterized by Electronic Feeding Equipment

Thomas G. Jenkins and Kreg A. Leymaster[1]

Introduction

Improvement in the efficiency of conversion of feed resources to acceptable edible product by domestic animals is desirable. This requires knowledge of the biological mechanisms which can be affected directly and (or) indirectly through modification of the genotype and (or) the environment. A mechanism that may be modified by genetic and environmental change is feed intake. Information descriptive of the modifications is limited due to the difficulty in accurately recording feed intake. Researchers have previously reported descriptions of automatic systems to record daily feeding behavior patterns in sheep. These devices required that the subject animal be housed individually, thus possibly disrupting flock behavior patterns that may be present.

The concept of automated systems to record feeding behavior data has been advanced through use of electronic instrumentation. An example is the instrumentation (Pinpointer 5000) being marketed by the AIS Corporation[2]. Animals are penned in a group with this equipment, but *ad libitum* feeding behavior data are collected for individual animals by limiting access to the feed stall to a single animal. Data collected by a microprocessor include individual animal identification, time of initiation of feeding activity, duration of the feeding period, ambient temperature, and feed consumption at each feeding event. The microprocessor(s) may be wired to a microcomputer to facilitate management of the data, which can become voluminous.

The primary objective was to evaluate the effect of number of animals housed in a pen upon free-choice feeding behavior of intact male lambs during the post-weaning period. This information would be of use in the investigation of factors affecting the efficiency of growth and consequently to improve the efficiency of growth through either genetic or environmental change.

Procedure

Two experiments (Exp. 1 and Exp. 2) were conducted in 1985. Trials were conducted within an enclosed building during June-July (Exp. 1) and August-September (Exp. 2). In each experiment, 72 rams were randomly assigned to treatments (pens) with 3, 7, 11, or 15 rams/pen. Each treatment was replicated once per experiment. Rams from a composite population originating from ½ Columbia, ¼ Hampshire, and ¼ Suffolk germ plasm were used. Rams averaged 65 days of age and 79 lb at the beginning of Exp. 1 and 100 days of age and 40 lb for Exp. 2. Prior to initiation of the study, rams were allowed a 4- to 7-day period to adjust to the facilities. A balanced pelleted alfalfa-corn ration (17% crude protein and 78.1% TDN) was provided free choice. Each pen was equipped with a Pinpointer 5000 unit. The feeding stall was limited to a single animal. Feeding behavior data were collected on a 24 hr basis for 21 days. For a feeding event, animal identification, time of initiation of activity, length of feeding activity (duration of feeding events, sec), ambient temperature (°F), and feed consumption (lb) were recorded. Approximately 25,000 feeding events were recorded from each experiment for the 21-day period.

Response variables descriptive of visit data were: average feed consumption/visit (lb), average time/visit (min), and rate of feed consumption/visit (lb/min). Daily average feed consumption (lb), average time in the feeding stall (min), and number of visits (v) per animal were also analyzed. These variables were analyzed with a model that included the mean effects of treatment (fixed), pen within treatment (random), and day (elapsed length of the experiment) as a covariant. Average weight gain/pen for the test interval and weight gain relative to average 21-day feed consumption (efficiency) were analyzed with treatment as a source of variation.

Results

Results from the analysis for Exp. 1 indicated that number of animals/pen affected the quantity of feed consumed/visit ($P<.05$) and the rate of feed consumed/visit ($P<.01$). Least-squares means for feed consumed/visit were .09, .16, .25, and .49 lb for number of lambs/pen of 3, 7, 11, and 15, respectively. Mean rates of feed consumption/visit (lb/min x 100) for the treatments of 3, 7, 11, and 15 rams were .6, .24, .30, and .30, respectively. Although not significantly affected by treatment, as the number of lambs housed in a pen increased, the length of time/visit (sec) tended to increase: 320, 303, 425, and 799 for 3, 7, 11, and 15 lambs, respectively. Expressed on a per-lamb basis, effects of animal numbers/pen upon feed consumption ($P<.10$), time spent feeding ($P<.01$), and number of visits ($P<.05$) were detected. Estimates for daily feed consumption/lamb were 3.2, 3.9, 4.0, and 3.4 lb for the treatment groups of 3, 7, 11, and 15 lambs, respectively. As the number of lambs/pen increased, the number of visits and time spent feeding/lamb decreased. The maximum number of visits/lamb/day (38) was observed for 3 lambs/pen, while number of visits/lamb for a pen of 15 lambs was 8 visits/day. The treatments of 7 (26) and 11 (17) were intermediate. A similar pattern was observed for time spent in feeding/lamb. Mean estimates for 3, 7, 11, and 15 lambs/pen were 182, 124, 116, and 94 min/lamb/day, respectively.

For Exp. 2, feed consumption ($P<.05$) and rate of feed consumed/visit ($P<.01$) were affected by the number of lambs in a pen. Least-squares means for feed consumption/visit were .12, .17, .21, and .35 lb/visit for the low to high treatment groups, respectively. Times spent/visit (sec) for the treatment groups of 3, 7, 11, and 15 were 283, 345, 345, and 554, respectively. The mean rate of feed consumption/visit (lb/min x 100) for the treatments of 3, 7, 11, and 15 rams were 1.6, 1.8, 2.0, and 2.9, respectively. Time spent feeding/lamb ($P<.01$) and number of visits/lamb ($P<.05$) were affected by the number of lambs/pen. Time spent feeding/day (min) were 121, 121, 107, and 90 for treatment groups of 3, 7, 11, and 15, respectively. As the number of lambs/pen increased, the number of visits (v) were 26, 22, 19, and 10 for the treatment groups of 3, 7, 11, and 15 lambs, respectively. Feed consumption/animal (lb) was 3.2, 3.7, 3.7, and 3.4 for the treatment groups of 3, 7, 11, and 15 lambs/pen, respectively.

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The configuration of the recording equipment was such that only a single lamb was able to feed at a time. With this restriction and a limited amount of time available for the consumption of feed in a 24-hr period, rams penned in the larger groups remained at the feeding stall longer and consumed a greater quantity of feed at each visit. Inspection of results expressed/lamb confirms this. The opportunity for an animal to visit the feeder decreases with increasing animal numbers. Thus, as an animal is restricted with regard to opportunity to feed, feeding behavior is modified by increasing the time spent feeding and the amount of feed consumed at each visit. The greater consumption/visit apparently is a manifestation of a modification of the rate of feed intake. At the higher pen group sizes (11 and 15), the rate of feed consumption was approximately 31% higher relative to a pen size of 7 and 300% greater relative to the rate of feed consumption of 3 animals/pen. These relative differences in consumption rates may be affected by choice of feedstuff fed to the animals. With greater access to feeder space (less competition) those lambs at lower numbers/pen were more frequent visitors to the feeder, but spent less time/visit and consumed smaller quantities of feed during each visit. The amount of feed consumed/day by an animal may be restricted by limited access to the feed stall and (or) a physical restriction to the rate at which feed may be consumed as suggested by results from Exp. 1. With restricted access to the feeding module and a probable physiological limitation to rate of feed consumption, increased lamb number/pen would limit the quantity of feed consumed by a lamb. If production required non-restriction of feed intake, moderate levels of animal numbers (9 to 11 animals/pen) would be required to utilize this equipment.

Weight gains during the test intervals for both Exp. 1 and 2 were not affected ($P>.10$) by number of lambs/pen. For Exp. 1, treatment affected ($P<.10$) feed efficiency (weight change, lb/feed intake, lb); least-squares means for feed efficiency of pens housing 3, 7, 11, and 15 animals were .29, .19, .19, and .32, respectively.

It is necessary to understand the effects of the number of animals housed in a pen on feeding behavior characteristics when using such electronic equipment in production. Competition among animals for entry into the feeding stall could modify these characteristics and the resultant change in performance of the animals. For example, expressed relative to the number of daily visits, the limitation imposed by the feeding stall resulted in greater feed consumption/visit by increasing the rate of consumption and length of time spent feeding for pens housing 15 lambs. Other researchers have reported similar results. These researchers compared eating behavior patterns of beef cattle with limited access to a feeding stall and trough fed animals. Fifteen animals were housed in the limited access pens and their rate of feed consumption per unit time was increased relative to the animals with access to a trough. However, because the number of daily visits/lamb was reduced in pens with 15 lambs, the daily feed consumption/lamb was similar to the feed consumption of lambs in the pens housing 3 lambs.

A Breeding Ram for All Seasons

Bruce D. Schanbacher[1]

Introduction

The domestic ram, like its primitive ancestors originating from nonequatorial regions of the world, shows cyclic reproductive responses to changes in daylength (photoperiod). Breeding activity is restricted to short days of autumn; thus lambing and the availability of lamb for the market place remain seasonal. Seasonal propagation of the species is associated with an annual cycle in testicular growth, and this cycle can be reproduced in the laboratory by artificial daylength. To avoid photo-induced refractoriness of intensively managed breeding sires exposed to either continuous short or continuous long daylengths, rams from this and other laboratories have been stimulated with relatively short photoperiodic cycles of alternating short and long daylengths. Herein are reported the results of testes size and plasma testosterone levels of mature Suffolk rams exposed to an artificial 8-week photorhythm.

Procedure

Twelve sexually mature Suffolk rams were randomly assigned to one of two treatment groups at the end of the fall breeding season and subsequently housed in photoperiod control chambers. Group I rams were exposed to alternating short (8L:16D for 4 wk) and long (16L:8D for 4 wk) daylengths for a period of 60 wk, or seven complete cycles. Group II rams were concurrently exposed to alternating short (8L:16D) and "pseudo-long" (7L:9D:1L:7D) daylengths. The split photoschedule was chosen because the presence of a 1-hr light flash at the 16th hour after subjective dawn had been shown previously to produce effects indistinguishable from those produced in response to 16 hr of continuous light. Testis diameter was monitored throughout the study with calipers after each 4-wk photoperiod exposure, i.e., immediately before the photoperiod change. At the same time, blood was collected by jugular venipuncture, and plasma testosterone levels were determined by radioimmunoassay. Testis diameter and plasma testosterone of six additional mature Suffolk rams (Group III) kept under natural daylengths were monitored during the course of this study.

Results

Testis diameter continued to decline during the winter and spring months in rams exposed to natural daylengths. Thereafter, regrowth of the testis was observed, with maximum testicular volume observed during the fall breeding season (October and November). Plasma testosterone levels for group III control rams are not shown but generally fell below 1 ng/ml during the nonbreeding season and then returned to breeding season values (> 4 ng/ml) the next fall.

Testis diameter of rams exposed to either of the two artificial 8-wk photorhythms differed from that of group III control rams after the third month. Whereas testis diameter continued to decline in controls, testis diameter of the photostimulated rams increased during the nonbreeding season. As a result, maximum differences in testis diameter (2 cm) were observed in early summer (June 24). Groups I and II photostimulated rams maintained an edge on gonadal size through the fall breeding season even though testis diameter of control rams had rebounded as expected. "Early" growth of the testis during the season of normal quiescence and the advantage maintained by these photostimulated rams over that of normally managed control rams appears to be coupled to stimulation of the brain-pituitary testicular hormone axis. Stimulation of luteinizing hormone and follicle stimulating hormone secretion by the pituitary (data not shown) and testosterone secretion by the testis (Fig. 1) are necessary for testicular growth, and this growth is positively correlated with sperm production. Importantly, the increased blood testosterone levels observed in April and throughout the remainder of the year were associated with increased sexual flush and increased incidence of Flehman and sexual preparedness.

Inadequate performance of the ram can contribute to less than optimum reproductive performance during the fall when both ram and ewe are expected to be fertile. Furthermore, reduced sperm numbers as a result of small testes size and reduced libido as a result of low plasma testosterone levels also contribute to the poor fertility of the domestic ram during the nonbreeding season. The findings reported here strongly suggest that an artificial

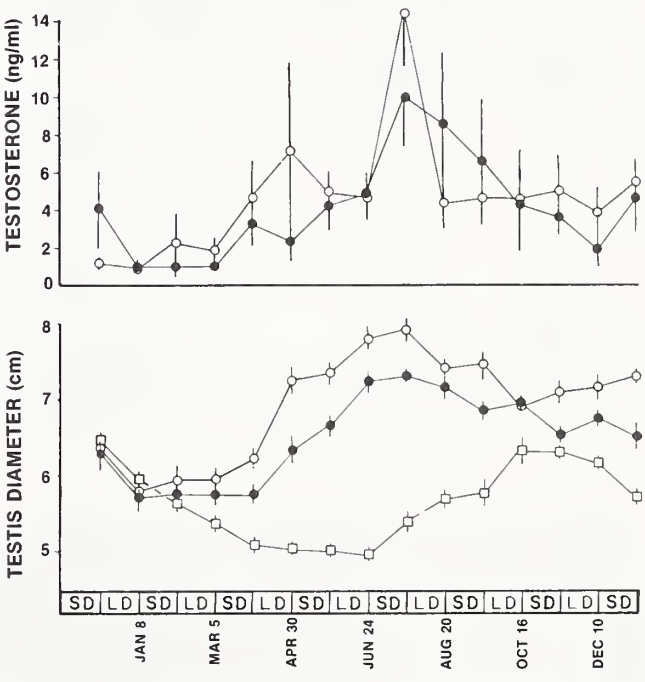

Figure 1—Longitudinal changes in testis diameter and plasma testosterone levels in control rams (□) and rams exposed to artificial 8-wk photorhythms consisting of short 8-hr days and either long 16-hr days (●), or pseudo-long days (7L:9D:1L:7D, o). Values are means ± SEM for six rams.

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8-wk photorhythm can stimulate endocrine, behavioral, and testicular events which are normally associated with reproductive success and which may be maintained indefinitely. Of particular interest is the finding that the stimulatory photorhythm can consist of short 8-hr days interspersed with either long 16-hr days or the utility-efficient "pseudo-long" daylength comprised of a 7-hr main light phase and a 1-hr light flash at night. Intermittent 4-wk exposure of these rams to either long or "pseudo-long" daylengths appears to have been sufficiently long to prevent the development of photo-induced refractoriness to stimulatory short days while intermittent 4-wk exposures to short days were capable of providing chronic stimulation to the testes.

In summary, exposure of Suffolk rams to specifically defined photorhythms consisting of alternating short and long days has been shown to overcome seasonal regression of the testis and to stimulate testosterone secretion and those behavioral traits necessary for their optimum breeding performance. Large testes size and elevated plasma testosterone levels were maintained through both nonbreeding and breeding seasons; therefore, these photostimulated rams may prove suitable for year-round use as breeding sires.

Immunostimulation of Male Reproductive Function: Leydig Cell Response to Estradiol Immunization

Bruce D. Schanbacher[1]

Introduction

Seasonal reproduction in sheep is the result of a complex interplay between the ensuing photoperiod and steroid negative feedback. Exogenous hormones and exposure to artificial stimulatory photoperiods have been used to induce ovulation and to produce lambs out-of-season. In spite of a wealth of information about the hormonal regulation of follicle development and sperm production and the involvement of both androgens and estrogens in the negative feedback mechanisms governing gonadotropin secretion, few attempts have been made to regulate reproductive performance by modifying steroid negative feedback. The most notable exception is the use of Fecundin* to enhance ovulation rate and thus prolificacy of the ewe. Similar products have not been developed for use in the ram, even though his sperm production rates and sexual aggressiveness are inadequate to properly service a flock of ewes during many months of the year. Herein are reported our initial findings on the effects of estradiol immunization on the pituitary-Leydig cell endocrine axis in sexually mature breeding rams. Estradiol was selected over other steroids because it plays a significant role in the control of gonadotropin secretion in the male and is believed to be the principle steroid involved in the regulation of seasonal breeding in both rams and ewes.

Procedure

Ten mature rams were randomly assigned to one of two treatment groups during the fall breeding season. Five rams were actively immunized against albumin and thereby served as controls, whereas a second group of five rams were actively immunized against an estradiol:albumin conjugate. Both primary and booster injections (1 mg each given in October, December, and February) were administered subcutaneously. Experimentation began in October at the time of primary immunization and extended into the nonbreeding season, a time when testosterone levels are generally suppressed. All rams were supplied a maintenance diet with water, salt, and mineral supplement provided *ad libitum*. All treatment responses were evaluated during the subsequent nonbreeding season.

Albumin- and estradiol:albumin-immunized rams were sampled in April via jugular venipuncture at 20-min intervals for 8 hr. Plasma samples were stored frozen until assayed for estradiol antibody titers and concentrations of follicle stimulating hormone (FSH), luteinizing hormone (LH), and testosterone. All rams were subsequently castrated under pentothal anesthesia, and pieces of testes were processed for morphological assessment of peritubular and perivascular Leydig cells. When circulating testosterone levels fell to nondetectable levels, estimates of testosterone metabolic clearance for albumin- and estradiol:albumin-immunized animals were made by calculating the decay curves of intravenously injected exogenous testosterone previously dissolved in ethanolic saline. Testosterone daily production rates were computed from the product of mean plasma testosterone levels and its metabolic clearance rate from blood.

Results

Immunization of mature rams against the estradiol:albumin conjugate resulted in the production of antibodies capable of binding radiolabeled estradiol (Table 1). These rams were found to have elevated mean plasma levels of FSH, LH, and testosterone when compared to control rams immunized against albumin. The nearly tenfold higher concentration of testosterone in estradiol immunized rams appears to have resulted from a tenfold increase in testosterone daily production rate (PR) since metabolic clearance rates (MCR) were not affected by immunization (Table 1).

Table 1—Mean plasma FSH, LH and testosterone concentrations and metabolic clearance rate (MCR) and production rate (PR) estimates for testosterone after immunization against albumin or an estradiol: albumin conjugate in sexually mature rams[a]

	Control rams	Estradiol rams
Antibody titer (binding at 1:1000)	< 0.5	39.8
FSH		
mean conc. (ng/ml)	1.9	4.3*
LH		
mean conc. (ng/ml)	1.4	3.3*
Testosterone		
mean conc. (ng/ml)	2.5	23.7*
MCR (l/day)	1959	1886
PR (mg/day)	6.3	64.2*

[a]Mean plasma hormone concentrations (n = 5) were calculated from an 8-hr intensive bleed in April.
*Significantly different from control ram value, $P<0.01$.

Estradiol-immunized rams had significantly heavier testes, and light microscopic inspection revealed that the heavier testes contained larger individual peritubular and perivascular Leydig cells (Table 2). Although total Leydig cell number per testis was not affected by treatment, total Leydig cell volume per testis was significantly increased.

Regulation of testicular function in general and Leydig cell function in particular is complex and involves gonadotropin inputs and negative feedback regulation by both androgen and estrogen. The present findings confirm the claim that estradiol plays a role in the feedback

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*Fecundin is a licensed product produced by Glaxo Australia Pty. Ltd. containing an androstenedione-protein conjugate immunogen.

loop and shows that the gonadotropin-Leydig cell interplay can be modified by immunization. Elevated gonadotropins in the presence of elevated plasma testosterone provide strong evidence for the conclusion that estradiol is the primary negative feedback steroid in the ram. It is convenient to be able to enhance gonadotropin secretion, Leydig cell function, and testis size immunologically without compromising androgen status. In fact, testis size, ejaculate volume, and sexual aggressiveness are each improved following estradiol immunization. If testosterone is normally below the threshold necessary for optimum reproductive performance during the spring nonbreeding season, as has been suggested by several authors, then elevation of testosterone secretion in the domestic ram via estradiol immunization provides a simplified approach for improving ram performance during both breeding and nonbreeding seasons. These investigations continue at MARC in an attempt to overcome seasonal suppression of reproduction in domestic sheep. An immunological solution to this production problem would be simple and practical and the benefit to the sheep industry implicit.

Table 2—Testis weight and Leydig cell size and number in sexually mature rams after immunization against albumin or an estradiol: albumin conjugate[a]

	Control rams	Estradiol rams
Testis Weight (gm)	17.3	219.3*
Cross sectional area (m^2)		
Peritubular Leydig cells	37.9	49.0*
Perivascular Leydig cells	45.9	57.9*
Leydig cell number/ testis (10)	13.1	12.3
Leydig cell total volume/ testis (cm)	2.62	3.66*

[a]Parameter means (n = 5) determined from morphometric analyses of testis tissue collected in April.
*Significantly different from control ram value, $P<0.01$.

Embryo Manipulation and Transfer in Sheep

Ralph R. Maurer[1]

Introduction

The uterine environment has been shown to influence growth and development of offspring. However, separation of the maternal environment and the genetic effects of the embryo is not easily done without removing the embryo from its natural mother. Through the use of embryo splitting and transfer, the influence of the maternal uterine environment and genotype of the embryo can be separated. In addition, reports using laboratory animals indicate that cells are exchanged between and among fetuses. Therefore, an experiment was designed to study the influence the uterine environment has on fetal and neonatal growth and development and to determine if one fetus can alter the development of another fetus. A second objective was to determine embryo survival rates when embryos were placed in either one or two uterine horns.

Procedure

Mature Suffolk and Dorset ewes were used as embryo donors, and mature crossbred ewes (½ Finnsheep, ¼ Rambouillet, ¼ Dorset) were used as recipients. The donors were superovulated as follows. The donors were synchronized either by placing a progestin sponge (30 mg fluorogestone acetate—Intervet France) intravaginally or by observing the date a ewe was marked by a vasectomized ram. On the twelfth day after the insertion of the vaginal sponge or day 12 of the estrous cycle (estrus = day 0) each ewe was injected intramuscularly with follicle stimulating hormone (FSH-P—Burns Biotic) following the regime listed in Table 1.

On the fourteenth day, 10 mg prostaglandin (PGF; Lutalyse—Upjohn) was injected intramuscularly at 7:00 a.m. and 10 mg PGF at 6:00 p.m. and the ewe placed with fertile rams fitted with a marking harness and chalk. Donors were observed twice daily for breeding marks.

Recipients were synchronized by placing a progestin sponge intravaginally. On day 12, each recipient received intramuscularly 10 mg PGF. On day 13, the progestin sponges were removed, and each ewe was observed twice daily for breeding marks.

Embryos were collected on days 5 to 8 of gestation and transferred to recipient ewes ± 48 hr of synchrony of the donor ewes. Embryos were transferred to both uterine horns if the recipient ewe had ovulated on both ovaries and to one horn if ovulation had occurred on only one ovary. Embryos were cut in half (half or split embryos) using forceps and a razor blade with an inverted microscope. No attempt was made to keep the half embryos in a zona pellucida. In the fall of 1985 two whole or two half embryos were transferred to each ewe, whereas in the fall of 1986 four whole or four half embryos were transferred. All ewes were allowed to carry the pregnancy to term. In 1986, all ewes lambed on their own, while in 1987, ewes were given 2 mg of a glucocorticoid (Flumethasone, Syntex) on day 146 of gestation to induce parturition and reduce dystocia.

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Table 1—Superovulatory regime

	7 a.m.	6 p.m.
Day 12	5 mg FSH	2.5 mg FSH
Day 13	2.5 mg FSH	2.5 mg FSH
Day 14	2.5 mg FSH & prostaglandin (PGF)	2.5 mg FSH and PGF

Table 2—Pregnancy rate by embryo type and number of uterine horns which received transferred embryos

Type of Embryos	Number uterine horns		
	One	Two	Total
Whole	22/25 = 88%	16/19 = 84%	38/44 = 86%
Half	24/42 = 57%	5/25 = 20%	29/67 = 43%
	46/67 = 68%	21/44 = 48%	

Results

Three hundred forty-two whole or half embryos were transferred to 111 ewes. Table 2 shows more ewes (86%) receiving whole embryos were pregnant than ewes receiving half embryos (43%). Pregnancy rate was also higher when all embryos were placed in one horn (68%) compared to two horns (48%). This was especially noted in ewes receiving half embryos (one horn = 57%; two horns = 20%). Embryo survival (Table 3) was also higher in whole (59%) than half embryos (17%). More embryos survived when placed in one horn (36%) vs two horns (29%).

Embryo age at transfer also influenced embryo survival as shown in Table 4. A higher percentage of day 7 and 8 embryos survived (38%) as compared to day 5 and 6 embryos (32%). Although no statistical differences were found in recipient day of gestation, Table 5 suggests that embryo survival may be increased if embryos from a donor ewe are placed in a recipient ewe which was marked after the time the donor ewe was marked.

Gestation length (Table 3) was influenced by year, number of lambs in the litter, embryo breed, and sex and was decreased by the use of a glucocorticoid. As would be expected, lambs born in 1987 had shorter gestation lengths (146.7 days) than lambs born in 1986 (149.5 days). Lambs born in litters of 1 or 2 had a longer gestation length than lambs born in a litter of 3 or 4. Suffolk lambs tended to gestate about 0.5 days longer than Dorset lambs and male lambs gestated 0.7 days longer than female lambs.

Birth weights (Table 3) were also influenced by number of lambs in the litter, year, and sex of lamb. Birth weights were heavier in 1986 (12.4 lb) compared to 1987 (9.0 lb), because of shorter gestation time and larger litters in 1987. Single and twin lambs were heavier than triplets and quadruplets. Male lambs were 0.6 lb heavier than female lambs.

Weaning weights calculated to 60 days were affected by number of lambs in the litter, number of lambs reared by a ewe, year, and transfer to one or two uterine horns.

Table 3—Percent embryo survival, gestation length, birth weight and calculated 60-day weaning weight for transferred embryos[a]

Type of embryo	Number uterine horns	Embryo breed	Percent embryo survival	Gestation length (day)	Birth weight (lb)	Calc. 60-day weaning weight (lb)
Whole	One	Suffolk	64 (59)	148 (36)	9.3	43.5 (22)
		Dorset	50 (14)	146 (7)	9.2	39.3 (6)
	Two	Suffolk	24 (90)	148 (22)	10.6	47.7 (17)
		Dorset	16 (43)	148 (7)	11.9	54.5 (7)
Half	One	Suffolk	58 (51)	146 (26)	8.0	41.8 (16)
		Dorset	44 (9)	146 (4)	10.5	39.2 (2)
	Two	Suffolk	12 (52)	149 (6)	12.2	56.7 (4)
		Dorset	0 (24)	000	000	000

[a]Numbers in parentheses are number of embryos transferred, number of lambs born, or number of lambs weaned.

Table 4—Embryo survival (percentage) by type of embryo and embryo age[a]

Type of embryo	Embryo Age (days)			
	5	6	7	8
Whole	56 (9)	58 (96)	59 (22)	83 (6)
Half	0 (12)	14 (133)	27 (60)	25 (4)

[a]Numbers in parentheses are the number of whole and half embryos transferred.

Table 5—Embryo survival (percentage) by embryo age and day of gestation of recipient[a]

Embryo Age (days)	Day of gestation of recipient[b]				
	4	5	6	7	8
5		33% (15)	0% (6)		
6	21% (19)	41% (123)	21% (73)	29% (14)	
7		56% (16)	32% (38)	33% (24)	0% (4)
8				25% (4)	83% (6)

[a]Numbers in parentheses are the number of whole and half embryos transferred.
[b]Day 0 = day of marking.

Single-born lambs were heaviest while quadruplets were lightest. For each additional lamb in a litter, the 60-day weaning weight decreased by approximately 8 lb. Single-reared lambs had heavier 60-day weaning weights than twins or triplets while nursery-reared lambs had the lightest 60-day weights. Lambs reared in 1986 were heavier (54.5 lb) than lambs reared in 1987 (43.4 lb). This can be attributed to smaller litter size and heavier birth weights in lambs born in 1986. Sixty-day weaning weights were heavier (45.8 lb) for lambs from embryos transferred to one uterine horn than lambs from embryos transferred to two uterine horns (44.2 lb).

In conclusion, whole embryos had a higher embryo survival rate than half embryos. Survival of whole embryos did not differ if transferred to one or two uterine horns. Half embryos had higher survival rates when transferred to one uterine horn. Day 7 and 8 embryos tended to have higher survival rates than day 5 or 6 embryos. Birth weights and 60-day weaning weights were influenced by number of lambs in the litter, gestation length, sex, and number of lambs reared by a ewe.

Effect of Weaning Lambs to a Dry Diet at 10, 14, or 28 Days of Age on Development at 42 Days of Age

Wilson G. Pond and Mike H. Wallace[1,2]

Introduction

The use of liquid milk replacers to rear lambs whose dams are unable to provide adequate maternal care is practiced commercially in flocks with high prolificacy. Lambs reared artificially on liquid milk gain weight normally. The high costs of labor, equipment, and milk replacer limit the economic feasibility of this practice. A dry feed, patterned after baby pig feed, has been used successfully to rear lambs weaned from liquid milk replacer at 10 days of age.

The purpose of the present experiment was to determine the survival, weight gain, feed utilization, and gastrointestinal tract response of lambs weaned to a dry diet at 10, 14, or 28 days of age.

Procedure

Thirty-two Finnish Landrace newborn lambs (12 to 24 hr old) were brought to a temperature-controlled room, given 50 ml bovine colostrum by stomach tube, and trained during the first day to suckle from a nursing bottle containing a liquid synthetic milk replacer. Lambs were selected from litters of three or four (two lambs left with each ewe). Lambs were penned singly in .75 x 3.0 ft raised wooden pens with steel mesh floors. Lambs were assigned sequentially at about three days of age to the following four experimental treatments: (1) weaned to dry feed at 28 days (DD28); (2) weaned to dry feed (Table 1) at 10 days (DD10); (3) weaned to dry feed at 14 days (DD14); and (4) weaned to dry feed at 10 days and given about 1 pint tap water twice daily through a nursing bottle from 10 to 28 days ($DD10H_2O$). Initial weight of all lambs was 5.6 ± .4 lb. Males were left intact and all lambs were docked during week 1. Individual body weights were recorded on entry into the pens (day 0), initially (day of assignment to treatment, day 1), and on days 10, 14, 17, 21, 28, 35, and 42. Feed intake (liquid plus dry feed) was recorded daily; and dry matter intakes from days 0 to 10, 11 to 28, and 28 to 42 and for the total experiment (days 0 to 42) were computed and used to compute efficiency of feed utilization (gain:feed ratio) during each time interval. Liquid milk replacer was prepared by mixing .55 lb of dry LAMAL (Carnation Company, Milling Division, Los Angeles, CA 90036) with 1.056 qt of tap water and fed *ad libitum* without heating.

Blood was sampled from the jugular vein of four lambs fed each diet on days 0 and 3 and at weekly intervals thereafter to 42 days for determination of hemoglobin, hematocrit, total plasma protein, albumin, glucose, urea N, and acetate. At 42 days all surviving lambs among those from which blood had been sampled were euthanized with phenobarbital, and liver, kidneys and total gastrointestinal tract were removed. Weights of liver, kidneys, full and empty rumen-reticulum, small intestine, abomasum, and cecum were recorded. The pH values of rumen and colon contents were recorded, and samples of strained fluid from each organ were frozen at -112°F until analyzed for volatile fatty acid concentrations by gas chromatography with a flame ionization detector.

Results

Effects of diet treatment on daily gain, dry matter consumption and gain:feed ratio are summarized in Table 2. Daily weight gain, dry matter intake, and gain:feed ratio during the first 10 days when all lambs received liquid milk replacer *ad libitum* were not significantly different among treatment groups.

From 10 to 28 days, DD28 lambs had greater daily weight gain and dry matter intake than other lambs. Gain:feed ratio was not significantly affected by diet, although the trend was for higher efficiency in DD28 lambs than in other lambs. Daily gain from day 29 to 42 was less ($P<.01$) in DD28 lambs than in lambs weaned to dry feed earlier, but mean daily dry matter consumed was not significantly affected by treatment. From day 0 to 42, DD28 lambs gained weight more rapidly than lambs weaned earlier ($P<.01$), consumed more dry matter ($P<.01$) and had a higher gain:feed ratio ($P<.01$) than other lambs.

The superior performance of lambs weaned at 28 days compared with that of lambs weaned at 10 or 14 days in the present experiment differs from a previous report in which daily weight gains were similar in lambs weaned to a dry diet at 10 or 28 days. Daily gains to 42 days of age averaged only .22 to .29 lb in those experiments compared with .28 to .43 lb in the present experiment. Unquantified environmental effects present in the current work compared with the previous report may account for these discrepant results. The previous experiments were performed in a large lamb nursery which accommodated several hundred lambs at once, whereas the present experiment was done in a clean room not previously or concurrently occupied by other lambs. Sanitation and probably a lower subclinical disease level in the present experiment may have favored superior lamb performance. In the previous work, voluntary intake of li-

[1]Pond is the research leader, Nutrition Unit and Wallace is the sheep operations manager, MARC.

[2]The full report of this work was published in Nutr. Rep. Int. 32:277-285, 1985.

Table 1—Composition of dry diet for early weaned lambs (fed in meal form)

Ingredient	Percentage
Oats, finely ground	10.0
Dried whey product	5.0
Alfalfa meal	10.0
Corn, No. 2 yellow dent	12.2
Dextrose	15.0
Hydrogenated vegetable oil[a]	5.0
Soybean meal	40.0
Dicalcium phosphate	1.5
Iodized salt	.5
Trace mineral premix F[b]	.4
Vitamin premix No. 7[c]	.2
Choline chloride	.2
Total	100.0

[a]Crisco; Proctor and Gamble & Co., Cincinnati, OH.

[b]Swine trace mineral premix; contains 75% ground limestone as a carrier; supplies the following ppm in complete diet: CuO, 10; $FeSO_4.7H_2O$, 160; MnO, 20; ZnO, 100.

[c]Swine vitamin premix. Supplies the following (units per lb of complete diet): vitamin A, 1,153 IU; vitamin D_3, 1,549 IU; vitamin E, 155 IU; vitamin K, 7.74 mg; vitamin B_{12}, 58 g; riboflavin, 11 mg; niacin, 62 mg; d-pantothenic acid, 46 mg; biotin, 194 g; thiamine, 4.8 mg.

Table 2—Effect of age at weaning to a dry diet on weight gain, dry matter intake and gain:feed in lambs (least-squares means)[a]

Diets	DD10	DD10H_2O	DD14	DD28[b]
No. of lambs	8	8	8	8
Survivors to 42 days	7[c]	3[d]	7[e]	8
Daily weight gain, lb				
0 - 10 days	.37	.33[f]	.33	.37
11 - 28 days	.14[f]	.21[f]	.18[f]	.50[g]
29 - 42 days	.40[f]	.40[f]	.46[f]	.33[g]
0 - 42 days	.28[f]	.29	.33[f]	.43[g]
Dry matter consumed, lb				
0 - 10 days	.39	.39	.37	.40
11 - 28 days	.35[f]	.35[f]	.35[f]	.56[g]
29 - 42 days	.72	.69	.81	.63
0 - 42 days	.48	.46	.52	.58
Gain/Feed				
0 - 10 days	.938	.829	.916	.919
11 - 28 days	.269	.739	.488	.767
29 - 42 days	.585	.565	.587	.539
0 - 42 days	.629[f]	.697[f]	.660[f]	.741[g]

[a]No effect of sex was detected; therefore, data for males and females were combined.
[b]DD = dry diet (see Table 1 for composition).
[c]One lamb died at 23 days of age.
[d]Lambs died or were removed from the experiment 19, 19, 20, 21, and 21 days of age.
[e]One lamb died at 27 days of age.
[f,g]Means on the same line without a common superscript are significantly different from each other (probability $<.01$).

quid milk replacer may have been curtailed in lambs continued on that treatment to 28 days because the capacity of the milk dispenser was insufficient to insure that milk was available at all times, whereas,in the present experiment, special care was taken to assure continuous access to liquid milk in DD28 lambs. Dry matter (including that from liquid milk replacer plus that obtained from dry diet) consumed by DD28 lambs in the present experiment was 10.0 lb from day 10 to 28, but only about 7.9 lb in the corresponding period in the previous report.

Hemoglobin and hematocrit of DD10, DD10H_2O, and DD14 lambs were lower ($P<.01$) than for DD28 lambs, suggesting suboptimal intake or utilization of iron (Fe) from the dry diet. The mineral premix included in the dry diet provided 160 ppm Fe to the complete diet. The quantitative dietary Fe requirement of the suckling-age lamb is not clearly established but would be expected to approximate that of other young mammals, including the pig, whose requirement at 11 to 22 lb body weight is 140 ppm. Whether the lower daily weight gain of lambs weaned to the dry diet at less than 28 days was causally related to their lower hemoglobin and hematocrit cannot be ascertained from the present data. There appears to be a need to establish more clearly the Fe requirement of early weaned lambs.

Plasma urea N was greater ($P<.05$) for DD10, DD10H_2O, and DD14 lambs than for DD28 lambs, reflecting either less efficient utilization of the N present in the dry diet or an excess of dietary N in relation to needs for net protein accretion. Total plasma protein and albumin were unaffected by dietary treatment, indicating that dietary protein adequacy was not a limiting factor in lamb growth. Plasma acetate concentration was similar for all groups throughout the experiment, suggesting that development of rumen function was not impaired by any of the diet treatments.

Diet had no effect on relative kidney or liver weight, full or empty rumen-reticulum, abomasum, cecum, or small intestine weight (percent of live body weight) or pH of rumen, abomasum, or colon contents. The absence of differences in full or empty gastrointestinal organ weights and in pH of contents indicates that age at weaning to a dry diet had no influence on physical development or digestive function in lambs slaughtered at 6 wk of age. Concentrations of volatile fatty acids in rumen and cecum contents at 42 days also were not affected by age at weaning, suggesting no long term adverse effects on rumen or lower gastrointestinal tract fermentation associated with early weaning in lambs. Previous work indicated that immature physical or physiological traits associated with gastrointestinal function may be related to rumen impaction and higher mortality in lambs weaned at 10 days of age compared with results in lambs weaned later.

In the present experiment, no death losses were attributed to rumen impaction, and only in DD10H_2O lambs was there an indication of a relationship between diet treatment and death. In this group, five of the eight lambs died or were removed between 19 and 21 days of age. These losses were associated with low intake of dry diet and a gradual decline in vigor and weight gain ending in death. In two cases, lambs found comatose in their pens were quickly revived by intravenous glucose administration. They were removed from the experiment and returned to the liquid milk replacer diet until vigor was regained.

There is no clear evidence from the results of the present experiment that physical or physiological immaturity of the gastrointestinal tract of lambs weaned to a dry diet at 10 days of age is an important factor in lamb survival. The data support the conclusion that the lamb weaned to a dry diet at 14 days of age rapidly becomes a functional ruminant. The limitations and adaptations of the gastrointestinal tract of lambs in response to age and diet need further clarification by serial gastrointestinal and metabolic measurements during growth of lambs weaned at various ages between birth and 28 days.

It is concluded that the lamb weaned to a dry diet at 10 or 14 days of age is a fully functioning ruminant by day 42 and that weaning at 10 days of age is associated with growth and survival at least equal to values obtained when weaning is at 14 days. Weight gain to 42 days may be increased by weaning at 28 days rather than at 10 or 14 days.

Effect of Milk Temperature on Survival and Growth of Artificially Reared Lambs

Mike H. Wallace, Wilson G. Pond, and Robert M. DeGregorio[1]

Introduction

Many recommendations regarding methods for artificially rearing lambs indicate a preference for *ad libitum* feeding lambs a reconstituted liquid milk replacer (LMR) that is maintained at a cold (39°F) temperature to reduce risks of spoilage. Also, many workers indicate that feeding cold milk causes lambs to consume smaller quantities at a feeding, thus reducing losses due to abomasal bloat and digestive upsets. Newer procedures involve the addition of small quantities (1 ml/gal LMR) of 37% formaldehyde to LMR, which greatly reduces the risk of milk spoilage when containers are cleaned daily. Limited data are available to evaluate the performance of lambs fed cold *vs* warm LMR which contains preservatives.

This experiment was conducted to compare the consumption and performance of lambs fed LMR which contained an acid-responsive food preservative (a formaldehyde substitute preservative) when fed at a cold (39°F) *vs* ambient temperature.

Procedure

This experiment utilized 168 Finnsheep, Dorset, and half-Finnsheep lambs between 12 and 48 hr old. (Lambs which were used were surplus to numbers their dams could rear.) They were assigned sequentially, in groups of four, to either cold or ambient temperature treatments. Breed and sex were distributed as equally as possible between treatments within each block. All lambs received colostrum feeding at or prior to nursery entry. Lambs were trained to use the artificial nursing apparatus, vaccinated with *Clostridium perfringens* type C and D antitoxin, docked, and vaccinated by ear puncture with contagious ecthyma during the first 7 days after entry into the nursery. Lambs were offered *ad libitum* LMR until 28 ± 3 days of age when the artificial nipples were removed.

A complete dry feed, (ground-mixed, alfalfa-corn-soybean meal, 80.5% TDN, 17.5% C.P.) was offered *ad libitum* from a small metal self-feeder. Weight of feed offered and refused was measured and recorded. Water was available *ad libitum* from a plastic pipe.

Lamb body weights were collected and recorded at nursery entry and at weaning. Date and causes of mortality and/or gross pathology were recorded. Lambs lost during the trial period were not replaced once a crate contained 16 lambs.

Lambs were housed in the nursery on expanded metal flooring in ten 4 x 8 foot artificial rearing crates. Each consisted of four pens of equal size with a common milk supply. Crates were sequentially assigned to either cold or ambient temperature LMR treatments. Liquid milk replacer was offered to the lambs via 3-inch diameter, 8-ft long, PVC pipe serving as a milk reservoir, and artificial nipple, tube, and valve assembly. The cold treatment was imposed by adding sufficient freezer packs to chilled LMR in the PVC pipes to maintain approximately 39°F temperature. Ambient treatment was imposed by allowing the milk temperature to fluctuate with the ambient temperature. LMR temperature was monitored and recorded when milk was added, 8 a.m., noon, and 4 p.m. daily. Quantity of milk not consumed prior to the daily cleaning and disinfecting was recorded.

Milk replacer was reconstituted by adding 2 lb of an experimental milk powder (Land O'Lakes, Inc., Fort Dodge, IA) to each gal of warm water (20 gal batches) and mixing in the tub of a wringer-type clothes washer. The LMR was then put in 5 gal plastic containers. No formaldehyde was added. Cold milk replacer was stored overnight in refrigerators for the next day's feeding. At the beginning of the experiment, warm LMR was stored at ambient temperature overnight. About 2 wk (4-02-86) after the experiment started, problems were noted regarding the warm LMR — it appeared to curd and separate, which caused milk tubes, nipples, and valves to plug. There was no indication by smell or feel that LMR was sour or spoiled. If remixed, it appeared normal. To overcome this problem, warm LMR was mixed the same day fed. Hence, it was normally fed at a higher-than-ambient temperature.

Ambient temperature and humidity of the nursery were constantly recorded and are summarized in Table 1. The data on average daily gain were computed from entry to 28 days. LMR and dry feed consumed and feed/gain were also computed for the same interval.

Table 1—Ambient temperatures and humidity

	Temperature, degrees F	Relative Humidity, %
3/19/86 - 3/26/86 - high	70	70
- low	63	34
3/26/87 - 4/02/86 - high	77	68
- low	63	18
4/02/86 - 4/09/86 - high	75	70
- low	64	22
4/10/86 - 4/17/86 - high	66	56
- low	55	20
4/17/86 - 4/24/86 - high	73	64
- low	63	40
4/24/86 - 5/01/86 - high	73	69
- low	63	30

Results

Results of this trial are summarized in Table 2. There were no apparent differences in the traits of survival, lamb growth rate, or feed/milk consumption of lambs fed *ad libitum* LMR at 76°F or 39°F. The lack of difference in LMR consumption between treatments in this trial is at variance with earlier studies which showed higher LMR consumption for lambs fed warm LMR. However, these results are in agreement with previous work showing no differences in survival or growth rate between temperature of LMR offered.

[1]Wallace is the sheep operations manager; Pond is the research leader, Nutrition Unit, MARC; and DeGregorio is a researcher at the Land O'Lakes Research Farm, Webster City, Iowa.

The consumption of dry feed was far below that expected, despite an apparently adequate quality and a constant supply. It is suggested that the low dry feed consumption may have been due to effects of digestive tract infections.

Despite strict adherence to sanitation procedures during the trial period, lambs exhibited considerable problems with scours on both treatments. The problems apparently originated in the lambing facilities. The scour problems appeared to be exaggerated on the artificially reared lambs, presumably due to the added stress placed on these lambs and the method of choosing individuals to be artificially reared. Only lambs which were in excess of the number that a ewe could rear (most cases 2 or 3) were chosen. Routinely, the smallest, least vigorous lambs in a litter were chosen for artificial rearing. Treatments for scours in the nursery included oral Gentocin, oral Furox, oral Tribrissen, oral kaopectate, I.M. pennicillin-streptomycin, oral dextrose-electrolyte solution, injected vitamin B complex and/or oral "probios." Since scours were noticeable below the slotted floors of the nursery crates, treatment was normally done on a pen/crate basis, but individuals with problems were not readily discernible.

Table 2—Growth and consumption of lambs fed cold *vs* ambient temperature LMR

	Treatment	
	Warm	Cold
Number lambs started	86	82
Number of pens	5	5
Percent weaned	72.1	78.1
Milk temperature, °F	76	39
Average daily gain (lb)	.236	.229
LMR consumption/lamb/ day (qt)	1.2	1.2
Total dry feed consumed (lb)	16	18

Table 3—Survival and performance of lambs fed labeled *vs* experimental LMR

	LMR	
	Label	Experimental
Number lambs started	16	16
Percent survival	62.5	68.8
Average daily gain (lb)	.2200	.2946
Lambs died to enteritis/ lambs entered (%)	31	25

Of the 24 lambs lost on the warm LMR and 18 lambs on the cold LMR, 19 (79.2% of deaths, 22.1% of lambs entered) and 9 (50.0% of deaths, 11.0% of lambs entered), respectively, died with gross pathological symptoms suggestive of enteritis due to *Escherichia coli*. Samples/lambs sent to the University of Nebraska Veterinary Diagnostic Laboratory in Lincoln, Nebraska, resulted in cultures of *Escherichia coli*. Some samples indicated other bacterial complications (*Campylobacter* spp).

Concerns about the overall low growth rate of lambs during the trial period caused us to run a short trial with no replications comparing the experimental LMR provided by Land O'Lakes and standard commercially available material (label) manufactured by Land O'Lakes. Two crates of lambs numbering 16 each were fed on labeled or experimental milk replacer. Both crates of lambs were fed reconstituted LMR which was made on one day, chilled in a refrigerator overnight, and fed the following day. One ml of 37% formaldehyde was added at mixing to the labeled LMR. No formaldehyde was added to the experimental LMR. There were no efforts made to control LMR temperature in the milk reservoirs. All lambs were weighed on 5-17-86 after they had been trained to use the artificial nipples. They were weighed again at weaning on 6-13-86 (27 days later) for experimental and 6-16-86 (30 days later) for label LMR. Table 3 presents the results.

Lambs fed the experimental LMR had a 34% higher rate of gain (ADG) than lambs fed label LMR. Albeit, individual lamb variation and lack of replication preclude statistical comparisons between diet treatment means. The higher rate of gain and survival of lambs fed the experimental LMR indicate that the LMR used in the earlier trial comparing cold and ambient temperature LMR was not the cause of the relatively low survival or poor growth exhibited.

Response of Lactating Ewes to Varying Levels of Protein in Corn Silage-Based Diets

Wilson G. Pond and Mike H. Wallace[1,2]

Introduction

The quantitative protein requirement of prolific ewes (> 1.5 lambs born/ewe) during lactation has not been thoroughly determined. Earlier reports suggested a total crude protein requirement of 10% or less. Other reports indicated that the level of milk production of ewes may be higher than previously recognized and that the protein requirement, therefore, may be higher. Later research indicated that the total protein requirement is approximately 10.5 to 11.0% of the diet for lactating ewes with either single or twin lambs. Based on observed feed consumption, the amounts of crude protein ingested daily to meet this need were calculated to be .506 and .583 lb for ewes nursing single and twin lambs, respectively. The crude protein content of the diet recommended in 1975 by the National Research Council (NRC) during an 8-wk lactation was 10.4 and 11.5% for ewes nursing single and twin lambs, respectively; in 1985 the NRC suggested 13.4 and 15.0%, respectively, for 154 lb ewes. The higher levels suggested in the more recent recommendations are based on data from recent research. The concept of rumen bypass of supplemental protein sources as a factor in affecting the response to protein supplementation appears to be important.

The present experiment was designed to determine the response of mature Finnsheep crossbred ewes and their lambs to incremental levels of soybean meal in the diet during an 8-wk lactation.

[1]Pond is the research leader, Nutrition Unit and Wallace is the sheep operations manager, MARC.

[2]The full report of this work has been accepted for publication in Nutrition Reports International (in press, 1987).

Procedure

One hundred ninety-two mature crossbred (½ Finnsheep x ¼ Dorset x ¼ Rambouillet or ½ Finnsheep x ¼ Suffolk x ¼ Targhee) ewes weighing an average of 150.3 lb were used from an original population of approximately 240 head. Following estrus synchronization through use of progesterone-containing pessaries, ewes were pen-mated to ½ Finnsheep x ¼ Dorset x ¼ Rambouillet males over a 7-day period and were grouped in drylot pens throughout gestation and fed a standard gestation diet sequence of a corn silage/soybean meal/alfalfa hay/corn diet providing 9.6% crude protein in early gestation and 11.9% crude protein during the last 6 wk of gestation. They were shorn 4 to 6 wk prior to parturition. On day 0, within 1 wk after parturition, ewes were assigned in groups of 12 to four replicate pens of each of the four diets shown in Table 1. Assignment was made on the basis of ewe age, genetic background and number of lambs suckled. To minimize feed refusals, the appropriate amount of feed for each diet was augured daily onto a conveyor belt. The feeder was accessible to all ewes in a pen. Body weights of all ewes and their lambs were recorded on days 1 (1 to 7 days postpartum), 28, and 56. Feed offered to each pen of ewes was recorded daily. Creep feed (17.1% crude protein diet composed of 20% alfalfa hay, 60% corn, 15% soybean meal, and 5% mineral-vitamin supplement) consumption was recorded for each pen.

One-half of the ewes in each pen were selected randomly on day 1 of the experiment for blood sampling (jugular puncture). The same ewes were sampled at wk 4 and 8 of the experiment for plasma total protein, plasma albumin, and plasma urea N.

Table 1—Composition of diets

	Protein level, % of DM			
Calculated:	10.0	11.5	13.0	14.5
Analyzed:	11.1	12.4	13.1	14.2
Corn silage	83.45	83.45	83.45	83.45
Alfalfa hay	10.0	10.0	10.0	10.0
Corn grain, ground[a]	5.6	3.7	1.8	--
Soybean meal	.2	2.1	4.0	5.8
Elemental sulfur	.05	.05	.05	.05
Iodized salt	.30	.30	.30	.30
Dicalcium phosphate	.40	.40	.40	.40
Vitamin premix[b]	+	+	+	+
Rumensin[c]	+	+	+	+
Total, %	100.00	100.00	100.00	100.00
Dry matter (DM), %	45.3	47.0	44.2	44.3
TDN, % of DM (calculated)	67.4	66.9	66.4	67.4
Crude protein, % of DM (N x 6.25)	11.1	12.4	13.1	14.2

[a]Ground to .64 cm.
[b]Supplies 1,056 IU vitamin A, 105.6 IU vitamin D and 10.56 IU vitamin E/kg diet dry matter.
[c]Rumensin provided 10 mg of monensin/kg of diet as a coccidiostat.

Results

Ewe body weight and feed consumption data are summarized in Table 2. Neither body weight change nor feed consumption was affected by lactation diet. There was a trend for single lambs suckling ewes fed higher protein levels to have greater daily gain. This trend suggests the possibility that a beneficial response to increasing levels of dietary protein was precluded in ewes suckling two, three, or four lambs due to an inability to consume an adequate amount of digestible energy to meet needs for lactation with the corn silage-based diet fed. Daily digestible energy intake recommended by NRC in 1985 was achieved only in ewes suckling single lambs (assuming feed consumption was similar for all ewes within a pen). There was a decline in body weight throughout lactation in all four diet groups (mean of 8.8 lb over the 8-wk period). Protein solubility in the rumen has also been shown to be a factor in ewe lactation. If one considers body weight maintenance as an index of protein adequacy, none of the levels fed could be considered adequate. The high level of corn silage (83.45%) in the diets fed in the present experiment may have precluded dry matter consumption at a level needed for body weight maintenance. Calculated mean daily protein intake was .74, .84, .93, and 1.11 lb for ewes fed 11.1, 12.4, 13.1, and 14.2% protein, respectively. These levels of intake are not sufficient to meet 1985 NRC recommended levels of protein for ewes nursing two or more lambs (.73 to .92 lb daily for 154 lb ewe nursing twins). However, none of the production traits measured provide evidence that levels of protein higher than 11.1% of the diet improved performance of lambs or ewes with the diets fed. Dietary protein level did not affect plasma total protein or albumin.

Table 2—Body weight and feed consumption of lactating ewes fed corn silage-based diets at four levels of dietary protein

	Protein level, % of DM				Overall
Item	11.1	12.4	13.1	14.2	mean
No. of replicates[a]	4	4	4	4	
Body weight, lb					
wk 0	68.1	68.0	68.3	69.0	68.3
wk 4	66.2	67.3	67.4	68.4	67.3
wk 8	63.3	65.4	64.3	64.1	64.3
Overall	65.9	66.9	66.7	67.2	66.6
Daily wt change/ewe, g	-.81	-.57	-.83	-.87	-.77
Daily feed consumed/ewe, lb	4.57	4.63	4.63	4.68	4.63
Daily DM/ewe, lb (calculated)	2.07	2.18	2.05	2.08	2.10
Daily protein/ewe, lb (calculated)	.74	.84	.93	1.11	.91

[a]Each replicate consisted of one pen of 12 ewes initially (total of 48 ewes/treatment); number of ewes that raised lambs was 45, 44, 43, and 46 for protein levels of 11.1, 12.4, 13.1, and 14.2%, respectively.

Plasma urea N was higher ($P < .01$) in ewes fed the three highest levels of protein than in those fed 11.1% protein, indicating that dietary protein was in excess of minimum needs in those diets or that net tissue catabolism of protein was under way as a result of the use of some of the protein ingested to meet energy needs of lactation in ewes fed these diets. Plasma albumin levels suggest that all levels of dietary protein were adequate to sustain normal lactation performance in ewes. Plasma albumin concentration would be expected to be depressed and plasma urea N elevated, rather than reduced, in ewes fed the lowest protein diet were it not adequate.

Lamb daily weight gain and creep feed consumption were unaffected by dam lactation diet (Table 3), although random assignment of ewes to lactation diet were associated with an inadvertent difference in mean number of lambs per ewe (1.74, 1.77, 1.91, and 1.89 lambs per ewe in diet groups 11.1, 12.4, 13.1, and 14.2% protein, respectively).

The overall mean daily weight gain of lambs to 8 wk (.45 lb) was comparable to that of other lambs of similar genetic background under the management practices of the sheep flock at MARC.

Increasing levels of crude protein from 11.1 to 14.2% of the DM in a corn silage-based lactation diet did not significantly affect lamb preweaning growth and body weight changes in mature Finnsheep crossbred ewes suckling 1.8 lambs under the management system used. Inability of lactating ewes to consume sufficient energy to meet needs when consuming corn silage-based diets or factors such as protein degradation in the rumen, which may affect overall protein nutrition of the ewe, need attention in future research directed toward determining optimum protein levels for ewes fed corn silage-based diets during lactation.

Table 3—Effect of lactation diet protein level on lamb preweaning performance

Item	Protein level, % of DM				Overall mean
	11.1	12.4	13.1	14.2	
No. of replicates[a]	4	4	4	4	
No. of ewes/replicate	45	44	43	46	
No. of lambs/ewe					
wk 0	1.74	1.77	1.91	1.89	1.83
wk 4	1.71	1.75	1.86	1.87	1.80
wk 8	1.64	1.78[b]	1.83	1.82	1.77
Overall[c]	1.70	1.76	1.87	1.86	1.80
Lamb wt/ewe, lb					
wk 0	16.9	15.4	16.3	16.3	16.3
wk 4	28.8	26.6	28.2	28.6	27.9
wk 8	43.1	41.4	42.5	43.1	42.5
Overall	29.7	27.7	29.0	29.3	29.0
Lamb daily wt gain, lb					
wk 0 to 4	.429	.405	.420	.438	.420
wk 4 to 8	.471	.462	.466	.477	.466
Overall	.447	.431	.438	.458	.447
Daily creep feed/lamb, lb	.480	.473	.471	.438	.466

[a]Each replicate consisted of one pen of 12 ewes initially (total of 48 ewes/treatment).
[b]One ewe died on day 52. This accounts for the higher value at wk 8 than at wk 0 and 4 in this group.
[c]Six, six, four, and three lambs died before 56 days in groups fed 11.1, 12.4, 13.1, and 14.2% protein, respectively.

Effect of Dietary Protein Level and Clinoptilolite on Growing-Finishing Lambs

Wilson G. Pond[1,2]

Introduction

Dietary protein level is an important determinant of body weight in lambs, but there is limited information available on the response of lambs to low protein intake during the finishing period. The total crude protein level recommended by the National Research Council for finishing lambs weighing 66 to 99 lb is 11.0% of the diet; male and female requirements were not separated. In Sheep Research Program Progress Report No. 2, published in 1984, we reported greater daily gain in intact male lambs fed corn-soybean meal or corn-fishmeal diets containing 14.2% protein than in lambs fed corn diets containing 10.5% protein. In the same experiment, a level of 2% clinoptilolite added to the high protein diet tended to improve weight gain. The mode of action of the beneficial effect of clinoptilolite may be related to its known ammonium ion exchange properties.

The present experiment was designed to determine the effect of dietary protein level on performance of intact male lambs of two genetic backgrounds during the finishing period and to evaluate further the response of lambs to dietary clinoptilolite supplementation.

Procedure

Sixty-four intact male lambs (24 Dorsets and 40 crossbreds representing advanced generations of a composite population of 50% Finnish Landrace (FL), 25% Dorset (D), and 25% Rambouillet (R) breeding) were assigned randomly within breed at a mean body weight of 37.9 lb to the eight diets shown in Table 1. From weaning, all lambs had been *ad libitum*-fed a high concentrate grower-diet. Lambs were kept individually in 2.5 x 3 ft pens with expanded metal floors in an enclosed, force-ventilated building and *ad libitum*-fed their respective dry diets in meal form (eight lambs/diet) from metal self-feeders throughout a 42-day experiment. Initial body weight of each lamb was taken as the mean of 2 consecutive days' weighings. Individual body weight and cumulative individual feed consumption were recorded biweekly for 6 wk. At day 42, all lambs were slaughtered after an overnight fast. Hot carcass weight (dressed weight immediately after slaughter), carcass quality score, leg conformation score, percentage of kidney fat, and dressing percentage were determined for each carcass.

Results

Effects of dietary protein level, clinoptilolite level, and breed are summarized in Tables 2, 3, and 4, respectively. Body weight gain ($P<.03$), gain/feed (as fed or adjusted by subtracting the weight of clinoptilolite in diets containing it; $P<.01$), and leg conformation score ($P<.03$) were affected by diet. Lambs fed 15% protein tended to gain more body weight ($P<.07$) during the 42-day experiment than those fed 10% protein. They also converted feed to body weight gain more efficiently ($P<.02$) and had a higher leg conformation score ($P<.03$). Feed intake was not affected by protein level. Additions of 2 or 4% clinoptilolite to the diet were associated with greater body weight gain ($P<.01$) and gain/feed ($P<.01$) than a level of 1%. Weight gain and gain/feed of lambs fed diets containing 1% clinoptilolite were not significantly different from those not fed clinoptilolite, although weight gain tended to be depressed by 1% clinoptilolite. We previously reported data suggestive of improved weight gain of lambs fed diets containing 2% clinoptilolite. The use of observed liveweights of animals as a measure of weight gain can be misleading because of possible differences in gastrointestinal fill associated with diet composition. Such a phenomenon seemed unlikely in the present experiment, because the use of adjusted final liveweight (hot carcass weight divided by mean dressing percentage) failed to change mean values appreciably. The present data illustrate the importance of level of clinoptilolite in affecting performance and provide confirming evidence that a level of 2% clinoptilolite with properties of the sample used is near the optimum for promoting weight gain and efficiency of feed utilization in finishing lambs. There was no interaction between dietary protein level and dietary clinoptilolite level in any trait measured, in agreement with previous work.

[1]Pond is the research leader, Nutrition Unit, MARC.

[2]The full report of this work was published in Nutr. Rep. Int. 32:855-861, 1985.

Table 1—Composition of diets (meal)[a]

Diet no.:	1	2	3	4	5	6	7	8
Diet designation:	HP, 0 clino	HP, 1% clino	HP, 2% clino	HP, 4% clino	LP, 0 clino	LP, 1% clino	LP, 2% clino	LP, 4% clino
Ingredient								
Alfalfa hay[b]	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Corn (ground)	71.65	70.65	69.65	67.65	85.55	84.55	83.55	81.55
Soybean meal	14.00	14.00	14.00	14.00				
Trace mineralized salt	.4	.4	.4	.4	.4	.4	.4	.4
Calcium phosphate	.4	.4	.4	.4	.5	.5	.5	.5
Ground limestone	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Vitamin A, D, E premix	.05	.05	.05	.05	.05	.05	.05	.05
Clinoptilolite (clino)[c]		1.0	2.0	4.0		1.0	2.0	4.0
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[a]As fed basis. High protein (HP), 0 clinoptilolite (clino) diet, 14.6% protein; low protein (LP), 0% clino, 9.5% protein.

[b]Sun-cured pellets (ground).

[c]Provided by Dr. R. Lauden, Double Eagle Petroleum and Mining Co., Casper, WY, from Buckhorn, NM, deposit; -50 mesh; mineral composition and cation binding properties were described by Sheppard and Gude.

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Table 2—Effect of dietary protein level on body weight gain, feed consumption, gain/feed, and carcass measurements of finishing lambs

Trait	Protein level	
	High	Low
No. of lambs	31	31
Initial body wt, lb	80.0[a]	85.1
Body wt gain to day 42, lb	26.2	23.5
Gain/feed to day 42	.197	.175
Adjusted gain/feed to day 42[b]	.201	.178
Slaughter wt, lb	103.2	103.8
Dressing percentage	51.3	50.9
Carcass quality score	11.6	11.9[c]
Kidney fat, %	2.4	2.2[c]
Leg conformation score	12.9	12.3[c]

[a]Mean.
[b]Feed consumption was calculated by subtracting appropriate percentages of clinoptilolite from weight of intake of diets containing it.
[c]Thirty lambs.

Crossbred (FL x D x R) lambs had greater body weight gain ($P<.01$), gain/feed ($P<.01$), percentage of kidney fat ($P<.01$), and leg conformation score ($P<.01$) than Dorset lambs. There were no interactions between diet and breed for any trait measured. Others have reported a higher percentage of kidney fat in FL crossbred lambs than in domestic purebred or crossbred lambs.

These data provide no evidence for breed differences in response to low protein, but suggest that 10% total crude protein in the diet may be inadequate for maximum growth and efficiency of feed utilization of finishing lambs of the genetic backgrounds used in this experiment. A level of 2% clinoptilolite (NH_4^+-exchange capacity of 1.58 meq/g) added to a high concentrate diet appears to be near the optimum for improved weight gain and gain/feed in intact male lambs during the finishing period.

Table 3—Effect of dietary clinoptilolite on body weight gain, feed consumption, gain/feed, and carcass measurements of finishing lambs

Trait	Clinoptilolite level, % of diet			
	0	1	2	4
No. of lambs	16	16	14	16
Initial body wt, lb	79.4[a]	86.0	82.9	82.1
Body wt gain to day 42, lb	24.9	22.2	27.1	25.3
Gain/feed to day 42	.188	.163	.203	.190
Adjusted gain/feed to day 42[b]	.188	.164	.207	.198
Slaughter wt, lb	99.2	105.8	106.7	102.1
Dressing percentage	52.0	51.6	50.7	50.1
Carcass quality score	11.9	11.6[c]	11.6	11.9
Kidney fat, %	2.3	2.4[c]	2.3	2.3
Leg conformation score	12.6	12.4[c]	12.9	12.5

[a]Mean.
[b]Feed consumption was calculated by subtracting appropriate percentages of clinoptilolite from weight of intake of diets containing it.
[c]Fifteen lambs.

Table 4—Effect of breed on body weight gain, feed consumption, gain/feed, and carcass measurements of finishing lambs

Trait	Breed	
	Crossbred	Dorset
No. of lambs	39	23
Initial body wt, lb	82.5[a]	82.7
Body wt gain to day 42, lb	26.6	23.1
Gain/feed to day 42	.194	.178
Adjusted gain/feed to day 42[b]	.194	.181
Slaughter wt, lb	104.5	102.5
Dressing percentage	50.3	51.9
Carcass quality score	11.8	11.7[c]
Kidney fat, %	2.7	2.0[c]
Leg conformation score	12.2	13.0[c]

[a]Mean.
[b]Feed consumption was calculated by subtracting appropriate percentages of clinoptilolite from weight of intake of diets containing it.
[c]Twenty-two lambs.

Protection Against Ammonia Toxicity by Clinoptilolite in Sheep

Wilson G. Pond[1,2]

Introduction

Urea toxicity is a serious problem in ruminant nutrition. Nonprotein nitrogen (NPN) provides a means of producing animal protein economically by utilizing the protein synthesizing capabilities of microbial populations in the rumen of the host animal. There is evidence that ammonia released from urea hydrolysis in the rumen is rapidly absorbed into the portal blood for transport to the liver from which some escapes to elevate carotid ammonia concentration, resulting in central nervous system derangements. Elevated blood glucose, lactate, and ketones are associated with ammonia toxicity.

Clinoptilolite is one of more than 50 naturally occurring zeolites (crystalline hydrated aluminosilicates of alkali and alkaline-earth elements). Given orally, it effectively binds ammonia to reduce the rise in portal blood ammonia concentrations in ammonia-intoxicated animals.

A clinoptilolite sample from the zeolite tuff at Buckhorn, New Mexico, (NH_4^+-exchange capacity of 1.88 meq/g) was selected for the present series of experiments. Experiments were designed to determine the ability of clinoptilolite to bind sufficient ammonia released from hydrolysis of toxic amounts of urea in rumens of adult female sheep to prevent or reduce clinical and metabolic signs of ammonia intoxication.

Procedure

Mature Rambouillet-Dorset-Finnsheep ewes were used. All experiments were conducted with ewes kept individually in raised metal pens (3 x 3 ft) with expanded metal floors in a temperature controlled (68 ± 4°F) room. Ewes were fed a dry diet containing 50% corn and 50% alfalfa meal (no urea) supplemented with fat soluble vitamins and minerals during all experiments. All experiments were administered by stomach tube in water solution (suspension for clinoptilolite) after a 16-hr fast. Blood was sampled from the jugular vein of each ewe before administration of the assigned oral doses (0 time) and at 30 or 60 min for four to six sampling intervals afterward. In Exp. 4 and 5, four rumen-fistulated ewes were used in a design in which each ewe was given each treatment in random order (water, urea, clinoptilolite, or urea and clinoptilolite) on four successive days. In Exp. 1, 2, and 3, ewes were fasted for 16 hr before administration of the test materials, while in Exp. 4 the daily allowance was fed after the final blood sampling and consumed before the following morning. This resulted in a 4- to 8-hr fast before administration of the test materials. In Exp. 5, ewes had access to feed *ad libitum*. The dosages of urea and clinoptilolite used in Exp. 4 were the same as those used in Exp. 1, 2, and 3 (1.1 g urea/lb body weight and 2.2 g clinoptilolite/lb body weight), while in Exp. 5, the amount of urea remained at 1.1 g/lb body weight, but the amount of clinoptilolite was increased to 4.4 g/lb body weight. Samples of rumen fluid were taken each time blood was sampled. Blood constituents measured at each sampling in each experiment were blood plasma ammonia, urea N, glucose, lactate, Ca, P, Mg, K, and Na. Rumen fluid constituents measured at each sampling in each experiment were pH, ammonia, urea N, glucose, and lactate.

Results

Results of Exp. 1 are summarized in Figure 1. Blood plasma ammonia concentration was increased dramatically by oral urea administration and reached a peak of 1,120 mcg/dl 1 hr after dosing. Clinoptilolite alone had no effect on plasma ammonia, but when given along with urea, plasma ammonia concentration reached a peak of only 640 mcg/dl at 1 hr. One ewe given urea alone showed severe clinical signs of ammonia intoxication beginning 30 min after dosage; neither ewe given urea plus clinoptilolite showed clinical signs. Plasma urea N, glucose, and lactate were increased dramatically by urea administration but not when urea and clinoptilolite were given together. These data suggested that administration of clinoptilolite at a weight ratio of 2:1 with urea offers protection against clinical and metabolic signs of acute ammonia toxicity in adult sheep.

In Exp. 2 and 3, urea administration dramatically increased plasma ammonia concentration as in Exp. 1. However, in contrast to results in Exp. 1, rises in plasma ammonia, urea N, and glucose were not inhibited by simultaneous administration of clinoptilolite. In fact, plasma glucose, which increases dramatically during acute ammonia intoxication, increased earlier and reached a higher peak in ewes given clinoptilolite and urea together than in ewes given urea alone, suggesting an aggravation of ammonia toxicity by clinoptilolite. In Exp. 2, both ewes given urea and clinoptilolite together died in acute tetany, one 2½ hr after dosing, the other about 4 hr after dosing. Clinoptilolite administered alone had no effect on any blood trait in either experiment. The different response of ewes to urea in the presence of clinoptilolite in Exp. 1 compared with that in Exp. 2 and 3 may have been related to the difference in diets fed prior to the experiments. Ewes in Exp. 1 had been changed from a corn silage diet to a dry diet containing 50% corn and 50% alfalfa meal just before the experiment; whereas, ewes in Exp. 2 and 3 had been acclimated to the corn-alfalfa meal diet for several weeks before the experiment.

Cation binding properties of clinoptilolite are well known. Urea toxicity is directly related to pH; a reduction in severity of clinical signs of ammonia toxicity has been reported in cattle by the direct ruminal administration of acetic acid (vinegar) following urea dosing. If clinoptilolite binds cations in the rumen so as to interfere with buffering capacity, an increase in rumen pH associated with this disturbance would be expected to result in more severe signs of ammonia intoxication.

Experiments 4 and 5 were conducted with rumen-fistulated mature ewes to permit monitoring of rumen pH and other factors associated with ammonia toxicity simultaneously with the monitoring of these same factors in blood. In Exp. 4, rumen pH was increased substantially by urea and to a yet greater degree by clinoptilolite and urea together in a 2 to 1 ratio by weight. Clinoptilolite alone had no effect on rumen pH or on rumen ammonia,

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[1]Pond is the research leader, Nutrition Unit, MARC.

[2]The full report of this work was published in Nutr. Rep. Int. 30:991-102, 1984.

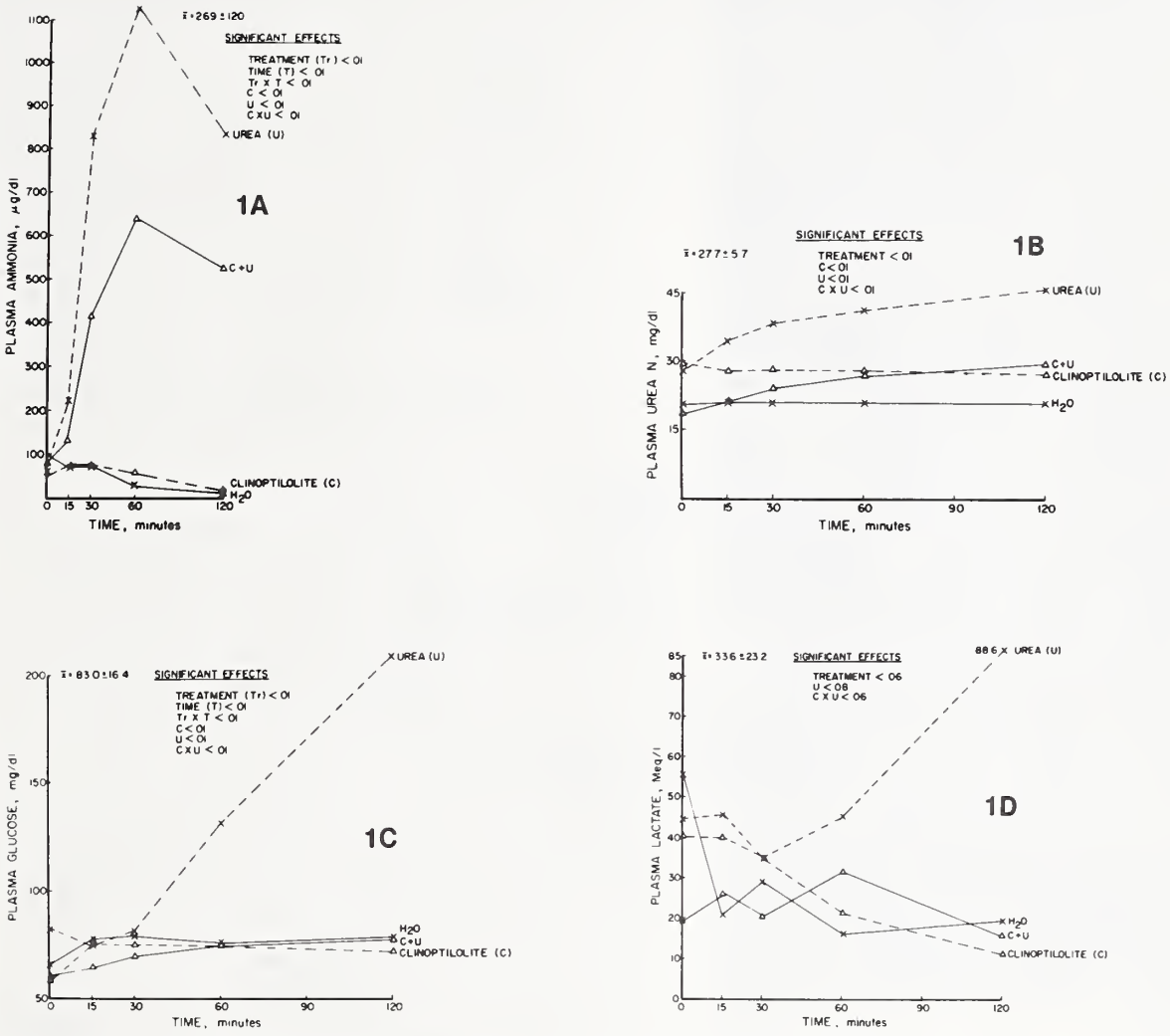

Figure 1—Effect of 0.5 g urea, 1.0 g clinoptilolite or both/kg body weight on plasma concentrations of ammonia (1A), urea N (1B), glucose (1C), and lactate (1D) in Exp. 1 (two ewes per treatment).

urea N, glucose, or lactate. Rumen concentration of ammonia was depressed during the first 1 hr. Ewes given urea alone had a dramatic increase in rumen ammonia to 2 hr while those given both clinoptilolite and urea continued to decline in rumen ammonia to 1½ hr.

Rumen urea N increased to a similar degree in ewes given either urea alone or urea plus clinoptilolite. Rumen glucose and lactate showed inconsistent trends with time after dosing. Plasma ammonia concentration was elevated dramatically by urea as in previous experiments; clinoptilolite plus urea resulted in a more rapid rise in plasma ammonia than when urea was given alone. (This effect may have been related to the more dramatic rise in rumen pH recorded when clinoptilolite was given with urea.) Clinoptilolite alone had no effect on plasma ammonia, urea N, glucose, or lactate concentrations.

Plasma glucose and lactate were elevated more dramatically by clinoptilolite plus urea than by urea alone in Exp. 4, in which a 2 to 1 ratio of clinoptilolite and urea was given. These indications of more severe ammonia intoxication were in accord with the more severe clinical signs observed in ewes given both compounds than in ewes given urea alone. One ewe given both urea and clinoptilolite had severe tetany, became comatose about 1½ hr after dosing, and was saved by emptying the rumen.

Plasma concentrations of minerals generally were not affected by treatment and are of doubtful value as indicators of ammonia intoxication. It is of importance that clinoptilolite administration at a single dose of 2.2 g/lb body weight in Exp. 4 appeared to have no adverse effects on plasma mineral concentrations.

Experiment 5 differed from Exp. 4 in that sampling intervals were changed to 0, 30, 60, 90, 120, and 240 min to extend the time over which rumen and blood traits were measured. Feed was available at all times, and the ratio of administered clinoptilolite to urea was changed from 2:1 to 4:1 (4.4 g clinoptilolite and 1.1 g urea/lb body weight).

Results of Exp. 5 are summarized in Figure 2 and Table 1. Ewes given urea responded similarly to the response in previous experiments, but the administration of clinoptilolite with urea offered clear protection against the rise and duration of elevation of plasma ammonia, glucose, and lactate. Rumen pH followed a pattern predictable in ammonia intoxication and reflected the protective effect of clinoptilolite against urea toxicity. Rumen ammonia, urea N, glucose, and lactate followed patterns predictable from Exp. 4. The low rumen ammonia levels in urea-dosed animals in the presence of high plasma ammonia were unexpected. One would expect much higher rumen concentrations than observed. Non-homogeneity of the rumen contents could have resulted in unrepresentative samples of rumen fluid. Hematocrit was elevated in ewes given urea alone, compared with that observed in other groups. This suggested a disruption of fluid distribution between plasma and interstitial tissues.

These data suggest that a ratio of clinoptilolite to urea of 4:1 in a single dose administered directly into the rumen of mature ewes given a toxic level (1.1 g/lb body weight) of urea offers protection against clinical signs of ammonia toxicity and death by virtue of its ammonium ion exchange properties. The ammonium ion exchange capacity of a specific sample of clinoptilolite is of major importance in determining the optimum amount of clinoptilolite administered to offset the toxic effects of a specific amount of urea given in a single dose.

Under the conditions of these experiments, 4.4 g clinoptilolite/lb body weight with an ammonium ion exchange capacity of 1.88 meq/g was needed to protect against ammonia intoxication in mature *ad libitum*-fed ewes dosed with 1.1 g urea/lb body weight. This ratio of clinoptilolite to urea (4:1) prevented clinical signs of ammonia toxicity but did not completely inhibit the rise in plasma ammonia and glucose and lactate associated with urea toxicity. The optimum ratio of clinoptilolite to urea for complete protection against excess urea ingestion would be expected to depend on the amount of urea ingested and the NH_4^+-exchange capacity of the clinoptilolite sample used.

Table 1—Overall treatment means for plasma Ca, inorganic P, Mg, and rumen ammonia, urea-N, glucose, lactate, Ca, inorganic P, and Mg of ewes (Exp. 5)

	Treatments			
	H_2O	C[a]	U[b]	C + U
Plasma traits:				
Ca, mg/dl	8.21	8.82	8.40	9.11
Inorganic P, mg/dl	4.53	5.13	5.01	4.91
Mg, mg/dl	2.02	2.18	2.21	2.12
Rumen traits:				
Ammonia, mcg/dl	893	832	1369	1177
Urea N, mg/dl	109	192	81	232
Glucose, mg/dl	101	102	88	97
Lactate, mg/dl	50	55	48	51
Ca, mg/dl	18.6	13.5	18.2	15.4
Inorganic P, mg/dl	55.5	57.2	53.8	46.1
Mg, mg/dl	8.6	5.8	7.9	6.6

[a]Clinoptilolite, 2.2 g/lb body wt.
[b]Urea, 1.1 g/lb body wt.

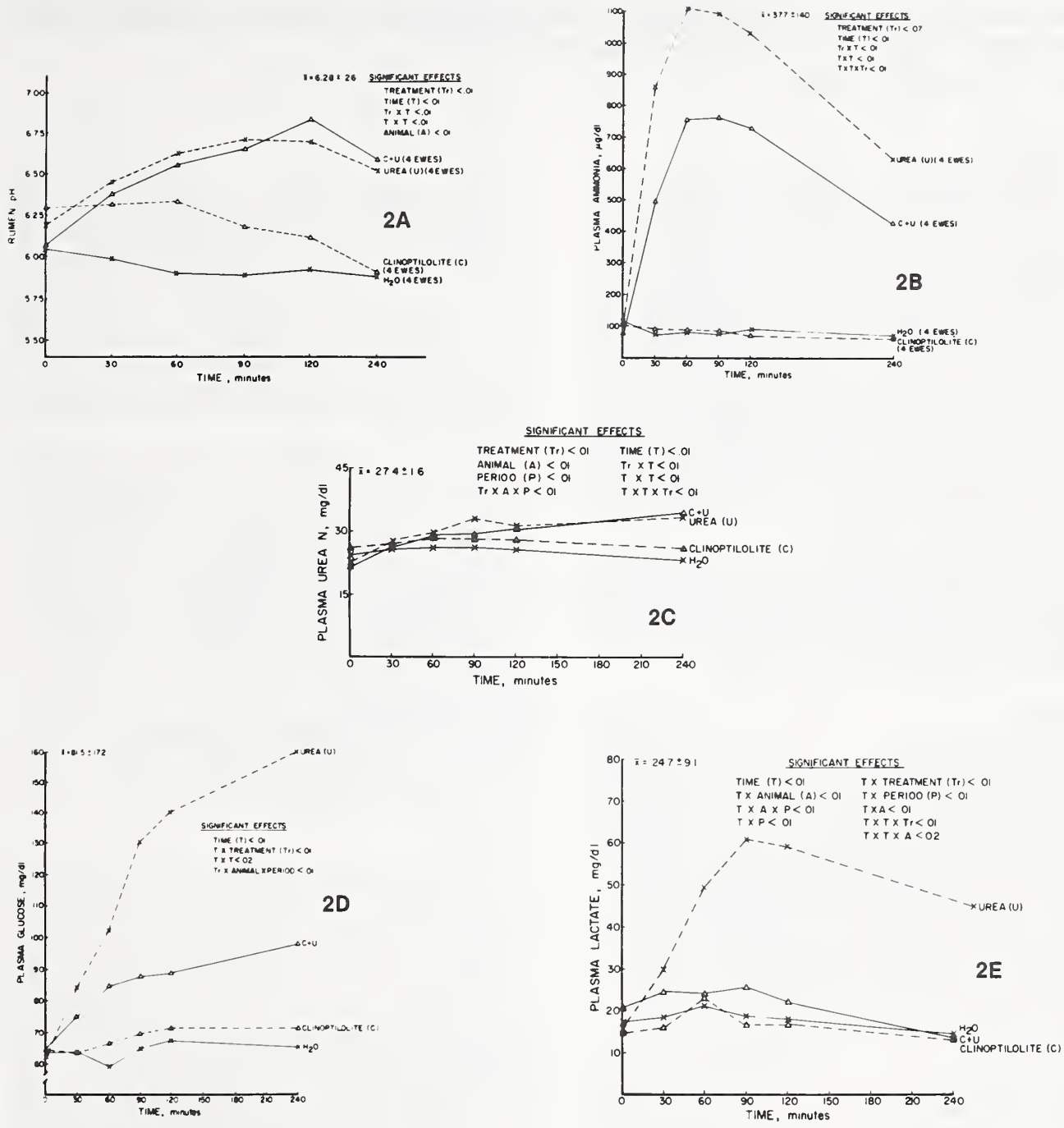

Figure 2—Effect of 1.1 g urea or 4.4 g clinoptilolite or both/lb body weight on rumen pH (2A), and on plasma concentrations of ammonia (2B), urea N (2C), glucose (2D), and lactate (2E) in Exp. 5 (four ewes used in a 4 x 4 Latin-square design).

Effect of Dietary Calcium and Zinc Levels and of Parenteral Vitamins A, D, and E During Gestation on Ewe and Lamb Performance

Wilson G. Pond and Mike H. Wallace[1,2]

Introduction

The National Research Council (NRC) in 1975 listed the dietary Ca requirement of 132 lb ewes at .24% of the diet during the first 15 wk of gestation and .23% during the last 4 wk of gestation and at .50% during the first 8 wk of lactation nursing single lambs or twins. These recommendations were changed in 1985 to .25% during the first 15 wk, .38% during the last 4 wk of gestation, and to .40 and .41%, respectively, for ewes nursing single lambs or twins during the first 8 wk of lactation. There is very little published information available on the quantitative Ca requirement of ewes bearing and suckling two or more lambs, but the greater skeletal Ca accretion of multiple fetuses and the greater milk secretion by ewes suckling two or more lambs suggests the possibility that current NRC recommendations are insufficient for highly productive ewes. Dietary Zn requirements of pregnant and lactating sheep are not well-defined.

The present experiments were designed to determine the effect of feeding levels of Ca and Zn higher than those recommended by NRC during gestation and lactation on reproduction and progeny performance in ewes. Possible interactions between dietary Ca and Zn levels in affecting the response also were evaluated.

Procedure

Exp. 1. Three hundred twenty multiparous Rambouillet ewes bred to Rambouillet rams and Synthetic I (composite of Finnish Landrace, Rambouillet, and Polled Dorset) ewes bred to Synthetic I rams, were assigned by breed and age to four diets in a 2 x 2 factorial arrangement of treatments. All ewes had been fed *ad libitum* a standard corn silage-alfalfa diet containing about .67% Ca, .34% P, and 20 ppm Zn before assignment to experimental diets. The diets were low calcium-low zinc, low calcium-high zinc, high calcium-low zinc, and high calcium-high zinc. Each diet (Table 1) was fed *ad libitum* to four pens of 20 ewes from about 8 wk of pregnancy until parturition of the first ewe in each pen, when all ewes in that pen were fed the corresponding lactation diet (Table 1) *ad libitum* through an approximately 8-wk lactation period.

Ewes were housed in an open-front, dirt-floor building with a southern exposure and outside lots. Each pen containing 20 ewes was 13 x 131 ft; daily rations were dispensed by horizontal conveyer into a feed trough extending the length of the pen to form pen lateral boundaries. Body weight of each ewe was recorded at the beginning of the experiment, at parturition, and at the end of lactation. Number of lambs born and individual lamb birth weight were recorded for each ewe; in cases of greater than two lambs born, randomly selected excess lambs were removed from the ewe at 1 day of age and transferred to a lamb nursery for bottle feeding on a liquid lamb milk replacer. Survival rate and weaning weights of survivors were recorded for all lambs.

Exp. 2. Three hundred ten multiparous estrus-synchronized Suffolk x Hampshire ewes bred to Columbia rams and Synthetic I estrus-synchronized ewes bred to Synthetic I rams were assigned by breed and age to the same four diets (Table 1) used in Exp. 1. Each diet was fed to four pens of 20 to 22 ewes (except there were only three pens of ewes fed HCa-LZn) from about 4 wk of pregnancy until parturition of the first ewe in each pen, when all ewes were fed the corresponding lactation diet (Table 1) *ad libitum* through an approximately 10-wk lactation period. Ewes were housed in the same building used in Exp. 1.

One-half of the ewes in each pen were randomly selected within breed to receive an intramuscular injection of a mixture of vitamins A, D, and E (500,000 IU of vitamin A, 75,000 IU of vitamin D_2, and 50 IU of vitamin E) at days 65 and 93 of the experiment to examine the possibility of a marginal vitamin D deficiency in ewes fed in confinement. Body weight of each ewe was recorded at the beginning of the experiment and on days 30, 65, 91, 140 (early lactation), and 184 (weaning). A blood sample was obtained on days 65 and 93 from all ewes in one replicate pen fed each diet for plasma Ca, inorganic P, Mg, and Zn (atomic absorption spectrophotometry) concentrations.

Number of lambs born and individual lamb birth weight were recorded for each ewe. Lambs in excess of two per litter were removed to the nursery as in Exp. 1. Survival rates and weaning weights of survivors were recorded.

Results

Exp. 1. Of 320 ewes started, 281 (87.8%) produced lambs. Barren ewes were present in all treatment groups. The data in Table 2 are based on only those 281 ewes. There were no effects of dietary Ca or Zn level during gestation or lactation on ewe body weight at parturition or at the end of lactation, fleece weight, number of lambs born and weaned, survival rate, or weaning weight. The overall mean number of lambs born per ewe was 1.63 ± .71 and the number weaned per ewe was 1.35 ± .67, equivalent to 82.8% survival among lambs kept with the ewe through lactation. Overall survival rate (including lambs raised in the nursery) was 85%. The data provided no indication that supplementation of Ca or Zn in excess of NRC recommendations significantly affected lambing rate, lactation, or lamb survival in ewes bearing a mean of 1.63 ± .71 lambs during pregnancy. There were no Ca x Zn interactions.

Exp. 2. Of 310 ewes started, 245 (79.0%) produced lambs and there appeared to be no effect of treatment on pregnancy rate. As in Exp. 1, there were no effects of dietary Ca or Zn level on any of the traits measured, and there were no Ca x Zn interactions (Table 3). Body weight of ewes in all treatment groups increased steadily during gestation and tended to increase from parturition to the end of lactation, indicating that feed intake was sufficient to maintain normal performance in all groups. Mean body weight of ewes was 140.1 lb 3 to 6 wk after breeding, 176.2 lb in late gestation, 151.6 lb in early lactation, and 157.3 lb at weaning. If Zn had been

[1]Pond is the research leader, Nutrition Unit, and Wallace is the sheep operations manager, MARC.

[2]The full report of this work was published in J. Anim. Sci. 63:1019-1025, 1986.

Table 1—Composition of gestation and lactation diets — Experiments 1 and 2

Ingredient	Gestation diets[a]				Lactation diets[b]			
	Low Ca Low Zn	Low Ca High Zn	High Ca Low Zn	High Ca High Zn	Low Ca Low Zn	Low Ca High Zn	High Ca Low Zn	High Ca High Zn
Corn silage	80.0	80.0	80.0	80.0	71.0	71.0	71.0	71.0
Alfalfa hay[c]	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Corn grain, cracked	7.5	7.5	5.6	5.6	13.5	13.5	11.6	11.6
Soybean meal, 44%	1.55	.55	1.85	.85	3.95	2.95	4.85	3.85
Elemental sulfur	.05	.05	.05	.05	.05	.05	.05	.05
Iodized salt	.30	.30	.30	.30	.30	.30	.30	.30
Vitamin premix[d]	+	+	+	+	+	+	+	+
Monosodium phosphate	.60	.60	.60	.60	.60	.60	.60	.60
Limestone			1.60	1.60	.60	.60	1.60	1.60
$ZnSO_4$[e]		1.00		1.00		1.00		1.00
Monensin[f]	+	+	+	+	+	+	+	+
Total, %[g]	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated values[h]								
Dry matter, %	46.9	46.9	46.9	46.9	49.5	49.5	49.5	49.5
Ca, %	.24	.24	.80	.80	.48	.48	.80	.80
Zn, ppm	20	74	20	74	20	74	20	74

[a]Fed at 5.3 lb DM/ewe daily (3,400 kcal DE/day) for the first 15 wk of gestation, full fed to parturition.
[b]Fed *ad libitum*
[c]Ground to .64 cm.
[d]Supplies 800 IU vitamin A, 100 IU vitamin D, and 8 IU vitamin E/g diet DM.
[e]$ZnSO_4$ added to diet at 150 ppm (54 ppm Zn) in a soybean meal carrier (1% of diet).
[f]Added at 7.7 to 9.9 mg/ton of DM for coccidiostat.
[g]In Exp. 2, one-half of the ewes in each pen were injected with vitamin ADE mixture twice during gestation.
[h]Basal diet contained 21 ppm Zn by atomic absorption spectrophotometry. Forage samples taken from cropland at MARC contained 20 to 26 ppm Zn and corn-silage contained 24 ppm Zn. Analyzed mean Ca concentrations of the dry matter of three samples of each of the low Ca gestation diets was .27% and of the high Ca diets was .79%; corresponding values for P were .31% and .32%. Analyzed mean Zn concentration of the dry matter of two samples of each of the low Zn diets was 27.8 ppm and of the high Zn diets was 60.0 ppm.

Table 2—Effect of gestation-lactation dietary calcium and zinc levels on reproduction and lactation, Experiment 1 (least-squares means)

Trait	Diet			
	Low Ca, Low Zn	Low Ca, High Zn	High Ca, Low Zn	High Ca, High Zn
Number of ewes[a]	68	74	71	68
Initial body wt, lb[b]	139.3	136.8	142.1	137.5
Parturition body wt, lb	141.5	137.7	142.8	140.1
End of lactation body wt, lb	148.5	147.2	144.8	146.5
Fleece wt, lb	8.1	7.9	8.4	8.6
Number of lambs born/ewe[c]	1.62	1.67	1.63	1.61
Lamb birth wt, lb	9.81	9.61	9.77	9.53
Number of lambs weaned/ewe	1.33	1.39	1.37	1.29
Lamb weaning wt, lb[d]	44.7	41.4	43.3	41.6
Survival rate, %[e]	86.0	86.0	86.5	81.5

[a]Eighty ewes (4 pens of 20 ewes) were originally assigned/diet. Data are included only for ewes that produced lambs and that survived through lactation. Data were analyzed on 281 of 320 (87.8%) of the ewes started.
[b]Number of day from beginning of experiment to parturition was 87.6 ± 6.9 day (87.2, 88.4, 86.9, and 87.9 day for low Ca-low Zn, low Ca-high Zn, high Ca-low Zn and high Ca-high Zn groups, respectively).
[c]Lambs in excess of two per litter, selected randomly from each litter, were transferred to nursery for bottle-feeding on day 1. No ewe nursed more than two lambs during the lactation period.
[d]Mean age at weaning was 59.4 ± 7.7 day.
[e]Includes lambs raised by ewes and in nursery.

at a marginal level, one would have expected reduced feed intake and body weights in pregnant ewes. Blood plasma concentrations of Ca, inorganic P, and Mg were unaffected by diet (Table 4), but plasma Zn concentration was less ($P < .02$) in ewes fed high Ca diets than in those fed low Ca diets, suggesting a reduction in dietary Zn utilization by high Ca, as commonly observed in swine. The absence of an effect of diet on lamb or ewe productive traits, however, suggests that any reduction in Zn utilization in response to high dietary Ca was without economically important effects.

Forage samples taken from alfalfa and corn silage grown at MARC contained 20 to 26 ppm and 24 ppm Zn, respectively. These levels of Zn correspond to published values but may be higher than reported in some areas of the U.S. and in other countries.

Zn deficiency signs have been described in ewes fed semi-purified low-Zn diets during gestation and lactation. Forages containing 20 to 30 ppm Zn have been associated with signs of Zn deficiency in ruminants. Improved reproductive performance of ewes has been reported in Australia by providing supplemental Zn to grazing ewes before mating and throughout pregnancy. Sporadic occurrences of Zn-responsive signs have been noted in scattered locations in the world (i.e., Australia, Finland, Guyana, Greece, Norway) despite plant Zn levels in excess of those considered adequate.

Injection of a vitamin A, D, and E mixture at days 65 and 93 of the experiment into one-half of the ewes in each group failed to affect plasma Ca, inorganic P, Mg, or Zn concentrations (Table 4), or any of the ewe or lamb production traits measured (Table 3). Therefore, evidence is lacking for a need for supplemental vitamins A, D, or E for ewes fed corn silage-hay diets in confinement during winter months in temperate regions.

Mean lambing rate was slightly higher in Exp. 2 than in Exp. 1 (1.89 ± .55 *vs* 1.63 ± .71, probably as a result of a higher proportion of Synthetic I ewes used in Exp. 2), but mean overall survival rate was similar (86.6 ± .3 *vs* 85.0 ± .3%). Lamb birth weights were similar, but mean weaning weight was greater in Exp. 2 than in Exp. 1 (51.0 *vs* 42.7 lb); the weaning age of 69 days in Exp. 2 *vs* 59 days in Exp. 1 probably accounts for the difference.

The data from two production-lactation experiments with a total of 526 (557) multiparous Rambouillet, Hampshire x Suffolk, and Synthetic I ewes indicated that currently recommended dietary Ca and Zn levels are adequate to support normal performance of animals maintained in confinement and fed diets comprised of corn silage, alfalfa hay, corn, and soybean meal, as assessed by ewe body weight, reproductive rate, lamb birth weight, weaning weight, and survival. No evidence was obtained for a beneficial effect of parenterally administered vitamin A, D, and E supplement during pregnancy, nor were there any Ca x Zn interactions or breed x diet interactions for any trait measured. Plasma Zn was reduced in one experiment in ewes fed high Ca diets, but the effect was not accompanied by adverse effects on ewe or lamb production traits. It should be pointed out that the relatively high intakes of all diets during early gestation in both experiments (approximately 4% of body weight daily) provided a total daily nutrient intake considerably above NRC recommendations, although concentration of Ca and, presumably, of Zn in the low Ca-low Zn diets were marginal. Concentrations of Ca and Zn in the drinking water were too low (60 ppm Ca and <1 ppm Zn) to contribute significantly to daily intake of either element.

Table 3—Effect of gestation-lactation dietary calcium and zinc levels and injected vitamins A, D, and E on reproduction and lactation, Experiment 2 (least-squares means)

		Diet							
		Low Ca, Low Zn		Low Ca, High Zn		High Ca, Low Zn		High Ca, High Zn	
Trait	Vitamin D injected:	No	Yes	No	Yes	No	Yes	No	Yes
Number of ewes[bc]		34	35	38	37	25	30	37	40
Fleece wt, lb		12.9	12.4	12.9	12.6	13.0	13.3	13.5	11.5
Number of lambs born/ewe[d]		1.83	1.78	1.84	1.89	1.92	1.94	1.94	2.00
Lamb birth wt, lb		10.1	10.8	10.2	10.6	9.2	9.8	10.1	9.9
Number of lambs weaned/ewe		1.48	1.60	1.54	1.73	1.65	1.60	1.56	1.79
Lamb weaning wt, lb[e]		53.7	54.8	51.3	50.6	47.1	50.4	51.0	49.3
Survival rate, %[f]		85.6	91.2	85.0	92.5	85.0	84.3	81.5	87.7

[b]Total ewes originally assigned per pen for low Ca-low Zn, low Ca-high Zn, high Ca-low Zn, and high Ca-high Zn treatments were, respectively: 22, 20, 20, and 20; 22, 20, 20, and 20; 21, 22 and 20 (three pens only); 21, 22, 20, and 20. One-half of ewes in each pen (11 in pens with 21 ewes) were randomly selected for intramuscular vitamin ADE injection (500,000 IU vitamin A, 75,000 IU vitamin D_2, and 50 IU vitamin E, RX Veterinary Prod., Porterville, CA, 93267) on days 1 and 65 of the experiment. Body weight and reproductive data exclude barren ewes and those that died before parturition. Data were analyzed on 276 of 310 (89.0%) of the ewes started.

[c]Number of days from beginning of experiment to parturition was 116.5 ± 6.0 days (116, 117, and 117 days for low Ca-low Zn, low Ca-high Zn, high Ca-low Zn and high Ca-high Zn groups, 116, respectively).

[d]Lambs in excess of two per litter, selected randomly, were transferred to nursery for bottle-feeding on day 1.

[e]Mean age at weaning was 71.3 ± 43.3 days.

[f]Includes lambs raised by ewes and in nursery.

Table 4—Effect of gestation dietary calcium and zinc levels and injected vitamins A, D, and E on plasma calcium, inorganic P, Mg, and Zn concentrations

		Low Ca, Low Zn		Low Ca, High Zn		High Ca, Low Zn		High Ca, High Zn		Time, day[a]	
Trait	Vitamin D injected:	No	Yes	No	Yes	No	Yes	No	Yes	65	93
Number of ewes[a]		9	10	11	9	7	11	10	11		
Plasma Ca, mg/dl		8.8	9.0	9.1	9.2	9.3	9.5	9.6	9.2	9.4	9.0
Plasma inorganic P, mg/dl		7.2	6.1	6.1	6.0	6.9	6.3	6.5	5.6	6.1	6.6
Plasma Mg, mg/dl		1.9	1.8	1.9	2.0	2.0	2.1	1.9	2.0	2.0	1.9
Plasma Zn, mg/dl		.77	.72	.75	.75	.68	.67	.68	.63	.72	.69

[a]Average number of days from start of experiment to parturition was 116.5. Therefore, blood sampled at days 65 and 93 of the experiment corresponded to approximately 52 and 70 days prepartum, respectively.

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